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GAS SUPPLY

IN PRINCIPLES AND PRACTICE.

A SIMPLE GUIDE

FOR THE

GAS FITTER AND GAS CONSUMER

BY

W. H. Y. WEBBER

Lecturer and Instructor to the Gas Sales Department Staff of The Gas
Light and Coke Co.; Author of "Town Gas and Its Uses," etc.

With numerous original Illustrations and Plates.

WHITTAKER & CO.
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PREFACE.

THE purpose of this handbook is to assist officers and skilled workmen engaged in the practice of Gas Supply Fitting, by offering them an epitome of sound principles and a condensed description of approved methods of carrying out the ordinary work of this department of British Gas Undertakings.

It is not intended to teach the elements of the handicrafts employed, nor to expound the theoretical sciences which underlie the technics of this service; but only to give such reasons for what is required to be done in the course of the Gas Fitter's everyday tasks, as may help to ensure good work.

The book has been compressed, as much as appeared practicable, by the omission of all detail matter which a tradesman with the laudable habit of following the technical press of his craft might be expected to know where to find elsewhere; and where borrowed illustrations are given it is for the exemplification of a type, rather than for any special distinction.

It is also hoped that users of gas who desire to obtain the best return for their expenditure will find in this little book something to their advantage.

W. H. Y. W.

1914.

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GAS SUPPLY.

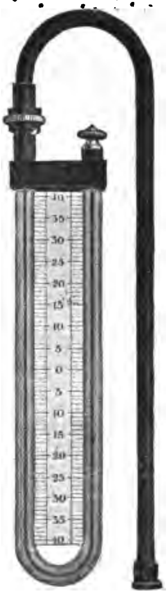
Pressure in Relation to Gas Supply.

The foundation of all sound knowledge and good practice in Gas Supply, is a sufficient understanding of the effects of Pressure.

The word "Pressure," as applied in ordinary gas distributing and supply practice, means (unless otherwise stated) the excess of the pressure of the gas in the pipes over that of the atmosphere.

In all gas-distributing systems it is absolutely required by law, and necessary in fact, that the pipes shall be kept constantly charged with gas "under pressure": first, in order to ensure that in the event of a breakage the gas shall always come out, and the air never enter (which would cause great danger); secondly, in order that the consumers who have contracted for a supply of gas shall not be deprived thereof by default of the undertakers. It follows from the latter condition that the *amount* of pressure necessary will be determined by the ordinary requirements of consumers' apparatus for utilising the supply contracted for. A very small positive excess of the gas pressure would satisfy the first condition.

Gas pressure is usually measured by the vertical height of a column of water which exactly counterbalances it. Therefore, it is also commonly termed *water-gauge* pressure; because it is indicated by the difference of level of the two surfaces of the water in the **U** gauge; which is the simplest form of this kind of apparatus.



THE **U** GAUGE.

The common name of this appliance refers to its shape, formed by bending a glass tube, the length of which, as bent, depends upon the amount of gas pressure to be measured. If such a tube when held vertically, open ends up, is half-filled with water, and one leg is placed in connection with gas contained in a pipe under pressure, the other leg being open to the atmosphere, the gas pressure will depress the level of the water on its own side, and consequently elevate it by an equal measure on the opposite side, against the constant and uniform pressure of the air. When the weight of the *total* length of the water column so displaced—downwards on the gas side, and upwards on the air side—equals the weight represented by the gas pressure, the movement of the water ceases; and the surface lines of the water in each leg of the gauge will remain at rest until the gas pressure changes, when the amount of water displacement will accommodate itself to the alteration, be it more or less.

When the displacement in question is small, as it generally is in ordinary Gas Supply—rarely exceeding six inches of water—it is customary to express it in *tenths of an inch.* Thus we should say in a particular case :—

" The District Pressure (that is, the pressure in the street mains, as controlled at the gas works or the distributing centre) is kept at 25-tenths during the off hours after 1 o'clock a.m., up to breakfast time, when it is increased to 30-tenths. On ordinary days it may drop to 25-tenths after the dinner hour; until lighting-up time, when it will be increased to 35-tenths and so remain until 11 p.m., when it will be gradually reduced down to the minimum at 1 a.m.; and so on daily."

The foregoing report implies that because all the consumers' appliances in the district need gas at about the uniform pressure of 20-tenths, owing to the increased demands at the busiest periods for cooking and lighting it is necessary to keep the street mains charged at a higher pressure at these times, in order to prevent the pressure at any burner falling below the actual requirement.

This example illustrates the importance of proper control of the gauge pressure, as an element in the satisfactory supply of gas. So much is this the case that it is an axiom in gas management that "Good Pressure means Good Gas, to the Consumer." Most complaints of "Bad Gas" that come to the gas office are found on inquiry to simply mean "insufficient pressure."

Gauge pressure originates at the gas works, where the weight of the gas holders expels the gas into the trunk mains; or sometimes the gas is started on its way by mechanical "boosters." The amount of pressure necessary at the starting point depends upon the minimum requirement of the most distant consumer or public street lamp in the district of supply, *plus* whatever loss of pressure may occur in transit, from heavy consumption intervening, or friction due to the length of piping. The effect of too small pipes, partly choked pipes, pipes going downhill, excessive draught of gas at points when pipes begin to rise uphill sharply—all and every obstruction or defect of the distributing system betrays itself by diminution of the gauge pressure at some point, which must be carefully watched for.

The outlet pressure at the works or source of supply is controlled by an appliance called the Station Governor. The purpose of this apparatus is twofold—first, to respond automatically to any increased demand for gas upon the district mains, without varying the pressure which it is set to give; secondly, to keep the outlet pressure constant, irrespective of variations of inlet pressure given by gasholders of different weights. It accomplishes these two purposes by one and the same operation. The essential feature of such a Governor is a valve in the gas-way moving without friction in relation to a seating, in such a manner that the area of clearance between the valve and the seating is enlarged as the outlet pressure falls, and diminishes as either the outlet pressure or the inlet pressure rises. The equable action of the valve is effected by forming it into a parabolic solid (like a sugarloaf) hanging concentrically with its seating, and suspended from the inside of a gasholder bell sealed in water, and so balanced that it rises (carrying the valve with it) as the inlet pressure increases, and sinks as the draught upon the outlet exceeds its normal balance upon the gas flow.

The accompanying sectional drawing (Fig. 1) illustrates the design and action of a good pattern of station governor, which has double parabolic cone valves that divide the flow of gas between them —one half going upward and the other half downward between the cones and their seating, so that equilibrium in any position is ensured. The gasholder bell is made with an annular air chamber at the bottom, to counterbalance its own weight and that of the valves; so that the vertical motion of the governor is sensitive to small variations of pressure, and also to the effect of weights added or removed from the top to alter the flotation level, and consequently the gas-way, thereby allowing more or less gas to pass at the determined pressure.

It will be perceived by this account of the Station Governor that it provides for both the *pressure* and the *quantity* of the gas sent out into the district of supply; but that, while its control of any excess of pressure on the inlet over what is required at the outlet is immediate and positive, its response to the demand for more gas in the district (as, for instance, by reason of a sudden fog) is actuated by the fall

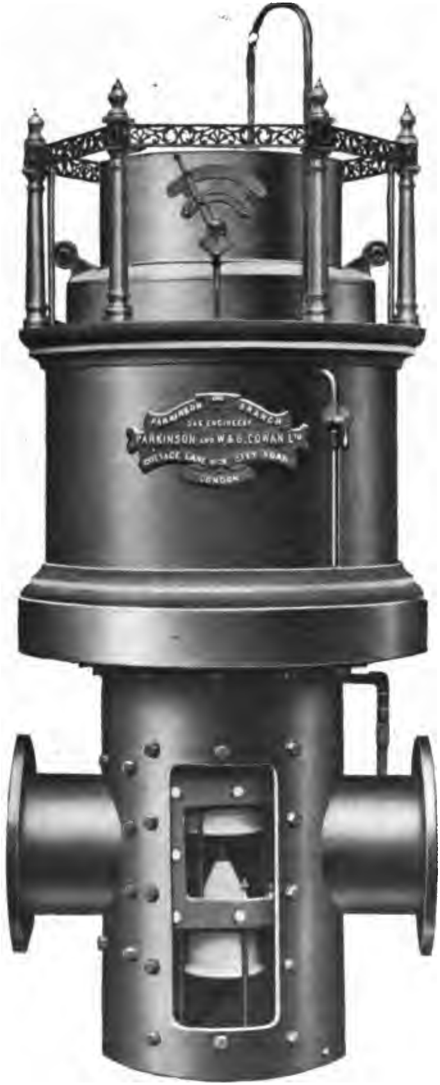


Fig. 1. A STATION GOVERNOR.

of outlet pressure, due to the simultaneous lighting up of burners and the increased draught upon the district mains, and is therefore consequential. That is to say, it is delayed through the interval of time required for the falling pressure to arrive back at the station; which may be far from the centre of heaviest consumption. Meanwhile the distant lights have gone dim, and may even threaten to die out altogether.

It is for this reason that ordinarily the adjustment of the station governor for maintaining the supply of the district in sufficient *quantity* has to be made by hand, in advance of the local need. This is done daily, as already explained, in readiness for the usual lighting-up times for cooking and lighting. The station governor is weighted down gradually, so that the rising of the pressure at its outlet shall indicate that the increasing demand is being met; until the full time arrives when the expected maximum draught has set in, and the governor attendant is master of the situation, and nowhere is the district short of gas.

Then, in due course, as the demand falls off once more, the district pressure backs up against the station governor; whereupon the weights are gradually removed until the minimum pressure is established. The accompanying illustration shows a governor station for the control of the district pressures from the high-pressure trunk main supply of The Gas Light and Coke Company, of London (Fig. 2).

The working of this Distributing Station is explained as follows:—

"Records of the pressures in the district mains are obtained, by means of registers, at 22 places, and these records, together with the initial pressure sheets at each Distributing Station, are sent to Goswell Road each day for examination, in order that it may be ascertained whether adequate pressures are given. As, however, the consumption of gas may greatly increase, owing to developments in districts where district registers are not fixed, and the increase may be in parts where the mains are of somewhat small diameter,

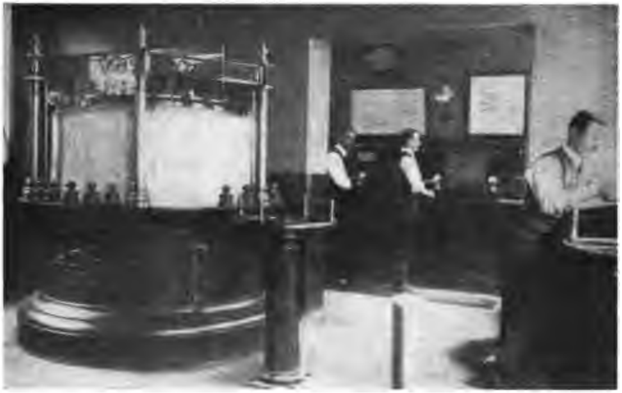


Fig. 2. Gas Distributing Station of The Gas Light and Coke Company, Goswell Road, London.

it is the practice to have pressures taken throughout the whole of the Company's district on a day when the consumption is at its heaviest. This general pressure taking usually takes place once in each year, by the district fitters, by means of water gauges, and the pressures are taken at the public lamps. The results are tabulated and charted on maps in order that it may be seen what mainlaying, if any, is required to be carried out in any part of the district for the purpose of maintaining adequate pressures under the heaviest consumption conditions."

It will be understood also from this explanation that the need for manual adjustment of the station governor in order to command the district pressures proceeds from the necessity of being beforehand, at the place of issue of the gas, with any change at the most remote pressure points (or points of consumption) which might interfere with the efficiency of the supply at such points.

Attempts have been made to supersede the human element in this duty of vigilance. It is clear that if there were always plenty of gas and ample margin of pressure on the station governor inlet, it would merely be necessary to cause the governor to open wider in the event of more gas being suddenly required in any part of the district. This call might be conveyed by the first tendency of the outlet pressure to drop, if the distance over which the pneumatic action had to travel was not too great. Such cases, however, are too rare to reckon with.

An ingenious device has been proposed, in which any quickening of the velocity of the gas flowing outward into the district (which would anticipate the actual drop of pressure) takes effect in opening the governor valves. The idea is attractive; but the responsibility is too great to be placed entirely upon a delicate piece of mechanism; and if a so-called "self-acting" machine must be looked after it is just as well dispensed with altogether.

The only way to directly control the loading of a station governor with reference to the requirements of a district of supply, is to connect the distant pressure point pneumatically or electrically with the governor station, so that the state of the pressure at that point is reproduced or indicated at the station. This can be done by laying a pipe or wire between the points in question. The former will actually reproduce the pressure at a considerable distance, and a governor can be actuated accordingly. The arrangement has been adopted for the control of a gas engine compressing gas for long distance transmission at high pressure.

[NOTE.—For details of Gas "Boosters" and High-Pressure Distribution Plant the student is referred to the numerous Papers on the subject to be found in the printed transactions of the Institutions of Gas Engineers and Managers.]

The Origin and Effect of Pressure upon Gas in Transmission.

THE accompanying diagram (Fig. 3) explains the origin of Gas Pressure. The gasholder having the floating weight (W) displaces the water of its tank by the vertical distance A B, at which height the displaced column of water weighs exactly the same as the holder. At any distance from the holder, a **U**-pressure gauge, upon the outlet gas main, will show the *same displacement of water*, provided that the gas in the main is motionless—that is, that there is no draught upon it. This condition may be considered as being practically fulfilled in the case of any gas distributing main, in a quiet district, during the few hours after midnight when only the public street lamps are alight.

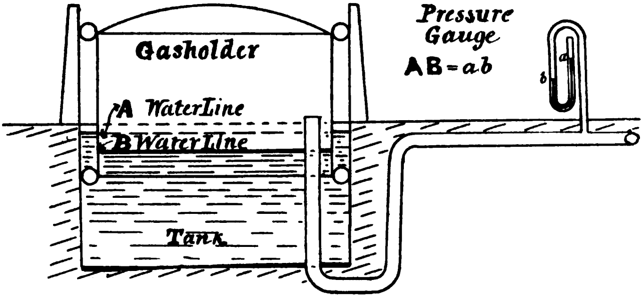


Fig. 3. DIAGRAM SHOWING ORIGIN OF GAS PRESSURE IN MAINS, AND ITS MEASUREMENT BY **U** GAUGE.

We are neglecting the station governor for the sake of simplifying the tracing of the pressure to its source.

Supposing the gasholder to be 100ft. in diameter and its floating weight (W) to be 100 tons. This then will be the weight of the water displaced by it. We must next ascertain the height of the displaced column of water. A ton of water is about 36 cubic feet in bulk; and here we have 100 times this quantity, or 3,600 cubic feet of water, displaced over a circular space 100ft. diameter; which is 7,854 square feet in superficial measure. Dividing the cubic measure of the water by this figure, we get the vertical height of the displaced column:—

$$\frac{3600}{7854}=0{\cdot}458 \text{ ft.}$$

Multiply by 12 to convert the answer into inches and tenths, we have $0{\cdot}458 \times 12 = 5$ inches and 5-tenths, nearly—say, 55-tenths, for the gauge pressure thrown by this holder; which, unless governed down by means of the station governor to something less, will be carried all over the district *supposing there to be no draught upon the mains.*

This condition will be that of pneumatic equilibrium. It is immediately upset by the commencement of a noticeable draught upon the system, as by lighting up a number of burners; whereupon the gas is expelled towards the openings by the fall of the holder.

Thus the prime cause of the flow of gas in the pipe system, and its discharge from holes opening into the atmosphere, is the force of gravity. When the gas and the holder are at rest, the force of gravity ready and waiting to set them in motion is said to be *potential.* The measure of the possible *kinetic* energy, or moving force, of the gas thus held up is given by the gauge pressure. The moment the gas is allowed to escape into the air it will rush out with a *velocity* corresponding to the energy of the *gravitation* of the holder.

The Velocity of the Discharge of Gas from Orifices opening into the Air.

THIS *velocity* will be that of a body falling freely from the height of a column of gas sufficient to exert the weight or potential force indicated by the gauge pressure.

Here we have a potential force represented by the weight of a column of water 5·5 inches, or 0·458 foot high. We must ascertain the corresponding height of a *column of gas* of equal weight. At the same temperature, water is about 1,640 times heavier than ordinary town gas composed of about three-fourths coal gas and one-fourth carburetted water gas, assuming the specific gravity of the mixture to be 0·50 (air = 1·0).

Therefore, the height of the column of such gas of equal weight to that of a column of water 0·458 ft. high is

$$1{,}640 \times 0{\cdot}458 = 751{\cdot}12 \text{ feet.}$$

The velocity per second acquired by a body falling from a height of 751 feet is given by the rule to be found in all Books of Physical Tables: "Multiply the square root of the height by 8." Here $8\sqrt{751} = 219{\cdot}2$ feet, which will therefore be the theoretical velocity or rate of flow per second of gas of the description in question, under a constant gauge pressure of 55-tenths of water column, discharging into the atmosphere at normal temperature and barometric pressure.

This theoretical rate of discharge of gas from a hole under pressure is subject to variation in regard to the *density* of the gas, as represented by its specific gravity. Strictly speaking, every inch of pressure under which gas is confined in a holder or in pipes increases its density. In practice, however, no correction is ever made for the small increase of density due to ordinary gasholder and main pressures. A correction may be made, and for some purposes is expedient, for differences of density due to the chemical composition of the gas itself. "Straight" coal gas is the lightest, having a specific gravity of between 0·42 and 0·43 (air = 1). No town gas distributed in the United Kingdom has a greater specific gravity than 0·5; which as already mentioned is about the specific gravity of the mixed gas very generally supplied.

The formula for calculating the theoretical velocity

(v) of discharge or flow of average quality gas of specific gravity 0·43, is

$$v = \sqrt{p} \times 100.$$

RULE.—Multiply the square root of the gauge pressure (in inches of water) by 100: the result will be the theoretical velocity and efflux of the gas from an orifice into the atmosphere, in feet per second. Deduct 10 per cent. in the case of samples known to contain up to 25 per cent. of carburetted water gas.

This theoretical result is subject to correction for the form of the orifice, which introduces the disturbing element of *friction*. If the hole is in thin plate the issuing stream suffers a considerable contraction beyond the actual opening. This effect is known as the "contracted vein," and it reduces the actual discharge to 65 per cent. of the theoretical velocity in the case of holes of regular shape, round or square.

With short cylindrical nozzles, two diameters long, the velocity increases to about 85 per cent. of the theoretical; which is important in relation to the design of gas discharging openings for very low heads of pressure, such as the bunsen burner holes of gas fires and boiling rings.

Referring to the foregoing data, we can now construct a Table of gas discharge velocities, for gauge pressures usually met with.

An important observation is to be made upon the figures of the following Table; which is that there is an exact relation between the gauge pressure and the velocity of the gas discharge. If we look out the theoretical rate of flow at 10-tenths pressure, which is 100 feet per second, we shall also notice that for 20-tenths it is 142 feet, and at 40-tenths 200 feet per second. That is to say, "The velocity of discharge varies as the *square root* of the gauge pressure."

There is reason to think that this relation does not hold for very high pressures, where the element of expansion of the gas on being liberated enters in. The facts, however, are not well determined.

TABLE I.

CALCULATED VELOCITIES OF DISCHARGE OF TOWN GAS.

Sp. gr. 0·43 (air=1); at 62° Fahr., bar. 30ins.

Water Gauge Pressure, tenths of an inch.	Coefficient of Discharge.		
	Theoretical. 1·0	Short Tube. 0·85	Hole in the Plate 0·65
	Velocity (approximate) in feet per second.		
1	31	24	21
2	44	34	30
3	54	42	36
4	63	48	42
5	71	55	47
6	77	59	51
7	84	64	56
8	90	68	59
9	95	72	63
10	100	85	66
15	123	105	81
20	142	121	92
25	158	134	103
30	174	148	113
40	200	170	130
50	224	190	146

In rising pipes the gauge pressure increases at about the rate of 1-tenth for every 10 to 12 feet of elevation, according to the specific gravity of the gas—the lighter gas showing the greater difference. This is a static effect, which is permanent whether the gas is at rest or moving. Formerly, a special form of governor, called a District Governor, was sometimes inserted in rapidly rising mains to check this effect of altitude; but this is not usual in modern practice. Where the local pressure on consumers' services is found to be excessive, for any reason, service governors are preferred. It may be necessary to watch the low-level district mains from which a rising main is fed, in order to provide a sufficient supply at the times of heavy drawing upon the rising pipe.

It would be a "counsel of perfection" to have a gas distribution and supply system so perfectly proportioned that an impulse of pressure imparted anywhere in the system would be carried equally all over it. This is the ideal, but the history and circumstances of few large public gas undertakings permit of its realization. In the imaginary case of laying out a new distributing system, the effect to aim at would be the maintenance of a uniform, invariable main pressure in the district mains of, say, 35-tenths of water gauge. This is sufficient to give the best results with all modern low-pressure gas consuming apparatus, including high-power lamps, allowing for unavoidable pressure-drop in the service pipes, at the meters, and in ordinarily good internal piping.

The Delivering Capacity of Gas Pipes.

REFERRING to the diagrammatic representation of the origin of main pressure (Fig. 3), it has been explained that it is there assumed that the gas in the main is at rest. This assumption was introduced for the sake of clearness in explaining the reproduction of the gasholder, or initial pressure, all over the district. As was remarked, this condition is only approximately realized in practice for a few hours in the dead of night, in quiet neighbourhoods.

Ordinarily, of course, the gas in the mains is in continual motion, flowing *at a velocity determined by the pressure drop* towards every open point of discharge. We have already seen what this relation is for a hole. In the case of a long pipe—which may be regarded as a hole with infinitely thick sides—another factor besides the dead weight of the gas, enters into the problem of the actual velocity for a given pressure, namely, the "skin" and the "molecular" friction of the flowing gas.

It may be stated as an axiom that all motion of one substance upon another is attended with friction, which tends to arrest the motion. In the case of moving fluids, whether liquid or gaseous, where different portions of the fluid move at different speeds, there is also friction in the body of the fluid, or molecular friction.

Gas in pipes, although certainly moving at different velocities, according to the position of the molecules at the centre of the tube or near the sides, does not ordinarily travel at so high a rate of speed as to render this internal friction noticeable.

It is only necessary, therefore, to have regard to the friction of the gas against the sides of the containing pipes, called the skin friction. This is a retarding force, which operates by reducing the pressure of the flowing gas. It is obviously greater for small pipes than large, for long pipes than short, for rough, corroded or coated surfaces than for smooth, for crooked pipes than for straight, and for heavy gas than for light gas.

The chief truth to bear in mind in regard to this matter of pipe friction is that it is physically impossible to move gas through a length of pipe without some loss of pressure. The precise amount of loss may not be exactly calculable by reason of the multiplicity of elements involved, and of the unknowable character of one of the most important—the allowance to be made for the nature of the interior surface of the pipe; which may in the course of its service get half-full of naphthaline or water. A certain degree of reserve in regard to the results of a purely mathematical treatment of the question of the delivering capacity of gas mains and pipes is therefore advisable. Yet it is not difficult to arrive at approximate conclusions.

The first points to decide upon are usually the quantity of gas to be delivered to a certain distance, and the permissible pressure-drop. We must know the minimum pressure at the starting point, and also at the finish. Deducting the latter from the former gives the amount of pressure-drop, which is available as "head," and may be spared for doing the work of delivering the gas.

For example: A supply of gas which is estimated to amount to a maximum of 3,000 cubic feet per hour, is required at a distance of 1,000 yards from the nearest adequate main, in which the pressure never falls during working hours below 35-tenths. The pressure at the point of delivery must not be under 30-tenths. Here we have the positive limit of 5-tenths for the head of pressure allowed to overcome the work of delivering the gas to the stated distance. The answer required is the diameter of the pipe.

There are several different formulæ for solving problems of this kind; but the one most familiar to gas engineers is Dr. Pole's:—

$$Q = 1350\, d^2 \sqrt{\frac{h\, d}{s\, l}}$$

conversely

$$d = \sqrt[5]{\frac{Q^2\, s\, l}{(1350)^2\, h}}$$

Where Q = quantity of gas delivered, in cubic feet per hour.
l = length of pipe in yards.
d = diameter of pipe in inches.
p = pressure loss in inches of water.
s = specific gravity of gas = 0·40, air = 1.

In the present example, the answer comes out at about 5½ inches. The quickest way to find the approximate size of pipe required is, of course, to seek it in the handy tables of Newbigging's "Handbook," where, on p. 280 of the latest edition, the delivery of 1,000 yards of 5in. pipe for gas of 0·4 specific gravity is stated at, for 5-tenths head, 2,508 cubic feet; and for a 6in. pipe, 4,210. In view of the probable higher specific gravity of the gas, the latter size would be chosen.

Another quick way of finding or checking the result is by using the Tavernier Gravet Slide Rule, as adapted to the Pole formula by the Keith-Blackman Engineering Company, London. This scale is adjustable for any specific gravity of the gas. It gives as the answer to the question in point, a diameter of 5½ inches for the pipe—in practice, of course, 6 inches.

Certain useful generalizations have been deduced from the Pole formula, of which the most easily borne in mind are the following :—" The Quantity delivered varies directly as the square root of the head of pressure."

(This deduction follows logically from considering a pipe as a long-sleeved hole—see Table I. Whether it is a question of the delivery of a pipe, or discharge from a hole, this rule applies equally.)

" The Quantity varies inversely as the square root of the length."

(That is to say, double the quantity can be delivered through one-fourth the length.)

" Double the length loses double the head."

(The head of pressure required to deliver a given quantity of the gas varies directly with the length of pipe.)

" The specific gravity affects delivery directly as the length."

(Both length, which means skin friction, and specific gravity, which means weight to be carried, are simple and direct resistances to the movement of the gas.)

The formula for computing the theoretical quantity of discharge of gas into the air from a hole in a plate or a pipe is :—

$$Q = d^2 \times \sqrt{p} \times 2{,}000.$$

Where Q = cubic feet of gas discharged per hour.
d = diameter of a fairly regular-shaped hole in inches.
p = gauge pressure, inches of water.

The same corrections for form of opening must be made as in Table I. In the case of a ragged, narrow rent in a plate or the side of a pipe, the discharge may not be more than half the theoretical quantity.

Absolute Pressure in Relation to Gas Supply.

THE term "Absolute Pressure" applied to gas, means the gauge pressure *plus* the pressure of the atmosphere, usually taken as standard at 30 inches of mercury, at the temperature of 60° Fahr.

Absolute pressure does not enter into questions of the discharge of gas through holes opening into the air, or through pipes; because the atmospheric pressure acts both ways—*i.e.*, on the holder to force the gas out, and also against the gas as it comes out. Therefore it cancels, and can be neglected in this regard.

The question of the absolute pressure comes in when it is requisite to ascertain the exact *bulk* of gas; which varies according to the amount of compression by which it is retained in its receptacle—holder, or pipe. The bulk of every gas varies also with the temperature, expanding or contracting by $\frac{1}{493}$ part of its volume at 32° Fahr. for every degree of rise or fall of temperature of the gas under a constant pressure; which is the condition of town gas supply. Roughly speaking, therefore, gas increases or shrinks in bulk by nearly 1 per cent. for each rise or fall of 5° Fahr. of its own temperature. No allowance for temperature, however, is ever made in practical gas supply and sale. (Strictly speaking, such correction should be made daily in respect of the output from the works, in order to effect a closer adjustment of this figure to the registration of the consumers' meters, and thus reduce the discrepancy which enters into the statistics of the "Unaccounted-for Gas.")

The effect of additional pressure over and above the atmospheric upon the density of gas is shown by the diagram (Fig. 4), which illustrates the operation of the physical law that, with constant temperature, the cubical space occupied by gas varies as the absolute pressure—$p\,v=1$; or

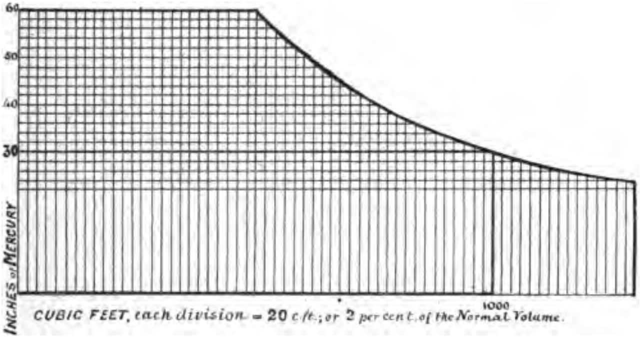


Fig. 4. Diagram Illustrating "Boyle's Law" for the Variation of the Bulk of a Gas with the Absolute Pressure—pv=1.

$$V^1 = \frac{Vp}{p^1}$$

Where V^1 = the required or final volume of gas.
V = the usual commercial or standard volume of gas.
p = the standard absolute pressure = (30 inches of mercury).
p^1 = the actual absolute pressure; also in inches of mercury.

EXAMPLE.—High-pressure gas, under 4 inches of mercury gauge pressure, is supplied to a consumer and measured by a meter working under this pressure. What correction is necessary to ascertain the true volume of such gas taken from the ordinary mains?

Assume a consumption of 1,000 cubic feet of compressed gas. Here the *final* volume of the gas is known, and the formula becomes

$$V = \frac{V^1 p^1}{p}$$

$$V = \frac{1000 \times 34}{30} = 1133$$

ANSWER.—The quantity chargeable at the ordinary price for gas under normal pressure is 1,133 cubic feet for every 1,000 cubic feet measured under a gauge pressure of 4 inches of mercury.

Mercury is about 13½ times heavier than water; therefore the comparative displacement of the two fluids in the **U** gauge is in this ratio. One inch of mercury pressure is roughly equal to ½lb. per square inch.

To convert inches of water pressure into mercury pressure multiply by 0·0735.

On the Continent gas pressures are stated in millimetres of water or mercury; 25 millimetres = 1 inch, nearly.

Also, gas is measured, under the metric system, in cubic metres. One cubic metre = 35·32 cubic feet, nearly; 1,000 cubic feet = 28·315 cubic metres.

Comparative Pressures
of
Mercury and Water, in lbs. per square inch.

(Approximate equivalents.)

Mercury inches.	Water inches.	Lbs. per sq. in.
0·1	1·4	0·05
0·2	2·7	0·10
0·3	4.2	0·15
0·4	5·6	0·20
0·5	7·0	0·25
0·6	8·4	0·30
0·7	9·7	0·35
0·8	11·2	0·40
0·9	12·6	0·45
1·0	14·0	0·50
2·0	27·0	1·00
3·0	42·0	1·50
4·0	56·0	2·00
5·0	70·0	2·50
6·0	84·0	3·00
7·0	198·0	3·50
8·0	112·0	4·00
9·0	126·0	4·50
10·0	140·0	5·00
11·0	154·0	5·50
12·0	168·0	6·00

Considerations affecting the Supply of Gas to Private Consumers.

It is advisable to keep a regular record of district pressures, by taking at intervals, according to the seasons, charts of a complete week's pressures at particular points. Instruments for the purpose, which may be placed in public street lamps, are to be had in various patterns of the makers. Too high pressures are as obnoxious to private consumers as an insufficiency, and chronic irregularities are more annoying still; especially in regard to the use of gas for cooking and many industrial fuel purposes. Inasmuch as doubling the pressure increases the discharge by nearly 41½ per cent. (see Table I), and that this is by no means an uncommon rise of pressure between the afternoon and lighting-up time, in some localities, it follows that on such occasions both the inverted lamps and the cook's adjustment of the gas oven burners may be completely upset. It would therefore appear to be expedient, where such irregularities of pressure are unavoidable, to provide the consumers likely to be prejudicially affected thereby with suitable pressure service governors, fixed *before* the meters.

Considerations of pressure are extremely important in respect to the planning of private consumer's service pipes, and internal piping. If the district main pressure may be supposed to average something between 35-tenths and 40-tenths during working hours, and the pressure at the consumers' meters is not to fall below 25-tenths, it follows that there is not more than 10-tenths to lose between main and burner, allowing the usual tenth, or tenth-and-a-half for the meter.

Example.—A residence requires a supply which for lighting, cooking, water-heating and fires may attain a maximum demand of 200 cubic feet per hour. The position of the meter (20-light) is 70 feet from the main. Required—size of service pipe, allowing for a pressure-drop of 3-tenths in its length. Gas of specific gravity 0·50.

The answer is 1in., by calculation; which, seeing that the alleged maximum demand would rarely arise, would probably meet the case; although the meter connection would be 1¼in., and this size would certainly be on the safer side for the service if naphthalene might be looked for. The large size pipe will cost 50 per cent. more; but the loss of head would be reduced to 1-tenth. The main cock may well be 1in.; as the extra local resistance due to the reduced bore would be inappreciable.

In connecting service pipes with the main, it is advisable to insert the pipe in the side of the main, not at the top. In this way the need for a bend is obviated, which is of advantage as lessening the chance of naphthalene collecting; and also of avoiding bringing the pipe so near the surface of the road. Some gas engineers prefer to drill the main one size smaller than the intended service, which is not a bad rule. Where a somewhat large service is taken off a rather small cast-iron main it is advisable to drill a pair of holes, each of one-half the required capacity, and unite the connection.

Well-painted steam tubing is now chiefly used for services in good soil, nothing smaller than one-inch tube being put underground. In case of a row of small houses with slot meters, the service may be branched outside the front wall. Services should if possible fall towards the main, to drain condensed moisture in this direction; never towards the meter. If the pipe must incline inwards, a sufficient drip-leg with plug at bottom must be inserted just before the meter. Great care must be observed in jointing all pipes and connections, by reason of the higher pressures now adopted, and also of the trying action of the oily deposit from carburetted water gas, and sometimes from the solvent oil sprayed into the gas as a preventive of naphthalene deposits.

For oily gas, including all gas that has passed through a pressure-increaser, the best mixture for making up screwed joints is given by Mr. Nisbet-Latta, Member of the American Gas Institute, as being composed of "equal parts of white lead, red lead, coach varnish, and driers." For ordinary use red and white lead paint is general. Semi-permanent screw joints, such as for consumers' governors, or stoves, can be made with spun-yarn, tallow and common black-lead.

The Delivering Capacity of Small Tubes.

TABLE II.

Showing Quantity of Gas of specific gravity=0·50, which will be Delivered in One Hour through Pipe of given size and length, with the Loss of Pressure stated, in tenths of an inch of water. For light coal gas, add 10 per cent. to the quantity.

Bore, inches.	Length, feet.	Pressure-loss, tenths.	Delivery, Cubic feet.	Remarks.
¼	9	2	4	Supply to Bracket.
⅜	12	3	30	Supply to fire.
,,	20	,,	17	Supply to lights only.
½	30	,,	40	
¾	50	,,	110	Service to ordinary public street lamps.
1	70	,,	200	Smallest service to private consumers.
,,	100	5	230	
1¼	100	,,	400	
1½	150	,,	550	
2	200	,,	1000	
3	450	,,	2300	

This Table gives the Delivering Capacity of the sizes of wrought iron pipes commonly used for services and internal carcassing, in lengths proportionate to a permissible loss of pressure. Gas assumed to be of specific gravity 0·50; for lighter coal gas add 10 per cent. to the quantity delivered. In using this Table as a guide to planning a scheme of carcass piping, start at the extremities of the system and work towards the meter. The lengths of pipes stated are over-all measurements, from burner point to the next sized pipe, or from one junction to another. Ordinarily, and except for very long lengths, changes of size are only to be made at junctions. Never supply gas from a smaller pipe to a larger one; except for a hanging lamp. The sizes of pipes required for meters, cookers, geysers and other fittings are found on the appliance itself.

The Table can also be used to find the delivery of gas for any other loss of pressure, by taking the ratios of the square roots: Always bearing in mind that losses of much more than 3-tenths in 100ft. run of piping are not considered good practice; except where a slot meter installation can be supplied by a ½in. pipe straight off at a good pressure, when it may be permissible to admit a much greater pressure-drop.

Relative Capacity of Tubes.

It is sometimes convenient to know the equivalent carrying capacity of different sized pipes. The following is approximately correct for proportionate lengths of branch pipes:—

One 1-inch pipe will feed *two* ¾-inch pipes; or *six* ½-inch; or *ten* ⅜-inch; or *twenty* ¼-inch. A 1¼ inch pipe has *double*, and a 1½ inch pipe nearly *four-times*, the carrying capacity of a 1 inch pipe.

TABLE III.

Square Roots of Gas Pressures, rising by tenths of an inch, from one-tenth to four inches.

Inches and Tenths.	Square Root.	Inches and Tenths.	Square Root.	Inches and Tenths.	Square Root.
0·1	0·316	1·5	1·225	2·8	1·673
0·2	0·447	1·6	1·265	2·9	1·703
0·3	0·548	1·7	1·304	3·0	1·732
0·4	0·632	1·8	1·341	3·1	1·760
0·5	0·707	1·9	1·379	3·2	1·790
0·6	0·774	2·0	1·414	3·3	1·817
0·7	0·837	2·1	1·450	3·4	1·844
0·8	0·894	2·2	1·483	3·5	1·870
0·9	0·949	2·3	1·516	3·6	1·897
1·0	1·000	2·4	1·550	3·7	1·923
1·1	1·049	2·5	1.581	3·8	1·950
1·2	1·095	2·6	1.612	3·9	1·974
1·3	1·140	2·7	1.643	4·0	2·000
1·4	1·183				

Service and Consumers' Governors and Regulators.

ACCORDING to what has gone before, the first piece of apparatus on a private service pipe may be a Governor, the purpose of which would be to reduce an excessive pressure and to equalize an irregular pressure. Hence the appliance will be classified as a Pressure Governor.

A governor is an appliance which operates automatically, by the action of the flow of gas upon a balanced valve. Governors are of two classes—Pressure Governors, which control the outlet pressure of the gas without respect to the quantity passing; and Volumetric Governors, which control the quantity of gas passed to a given maximum, irrespective of inlet pressure variations.

The economy of proper governing has long been recognised in gas supply practice, especially in respect to the public street lighting service. Volumetric governors were early installed in public street lamps, for the purpose of ensuring the constant rate of gas consumption contracted for. When the flat flame burners formerly employed were replaced by incandescent burners, governors were for a time discarded; but they are now generally restored, to the great advantage of the service. This, indeed, is the proper use for the volumetric governor.

It is the function of the Volumetric Governor to control the flow of gas to one particular point, in a predetermined quantity per hour; consequently they are maximum rate controls and can only be used for a

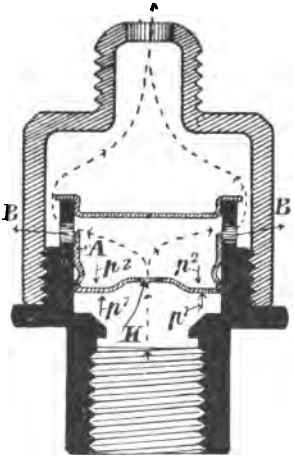


Fig. 5. Volumetric Governor.

single point. The accompanying figure (Fig. 5) illustrates the design of such a governor; the principle being that a disc A, moving with as little friction as is competent for a practically gas-tight contact with the inside of a cylindrical chamber, floats suspended between two gas pressures. Gas first strikes the underside of the disc and lifts it up momentarily to its highest point; but meanwhile gas has also passed up through the small hole K, to the upper side of the disc and escapes through the side holes BB. The weight of the disc now causes it to drop until this weight, *plus* the reduced pressure of the gas above it, released on its way to the burner, equals the inlet pressure. Thus the differential pressure p_1—p_2 is always the same, and any disturbance of the equilibrium causes the disc either to rise or fall, thus diminishing or enlarging the area of the gasway through the ports BB. Thus a uniform flow of gas is assured, whatever the variation of the inlet pressure.

A drawback of this type of volumetric governor is the contact-rubbing of the disc against the sides of the chamber, which leads to occasional jamming. Another pattern of street lamp governor, with a leathern diaphragm suspending a valve at the end of a flexible thread (C. Carpenter's Patent) avoids this risk.

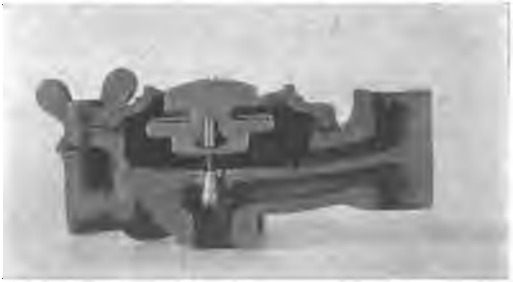


Fig. 6. Carpenter's Volumetric Street Lamp Governor.

(Flexible valve suspension ensuring accurate centring.)

The Pressure Governor may be of various designs, and intended to control widely different ranges of pressure, but it embodies the same principle, namely, that a pre-determined outlet pressure buoys up a suspended valve (as in the station governor already described), and only allows of the passage of just so much gas, at any inlet pressure, as will maintain the said outlet pressure. The illustration (Fig. 7) is a section drawing of a "Clark-Williams" consumers' pressure governor, one of the latest and most compact forms.*

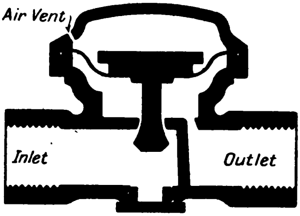


Fig. 7. CLARK-WILLIAMS PRESSURE GOVERNOR.

The correct place for a service governor is between the main cock and the meter. With regard to the main cock it should be impressed upon consumers that its proper use is simply to turn on and off the supply, in case of examination, cleaning, repair, &c., of the meter or the internal piping. It is not intended to be used to "regulate"—*i.e.*, reduce the supply pressure, which would upset the incandescent lights.

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* For a fuller explanation of the physics of gas governing, see J. G. Clark, "Transactions of the London and Southern District Junior Gas Association, Session 1911-12."

Neither is it advisable to shut the main cock every night, in the case of ordinary households. In large establishments it is expedient at night to by-pass the big main cock with a small pipe and cock, in order to keep the inner piping full of gas and the pilots alight, whilst not admitting a full supply to the premises.

Regulators are non-automatic appliances fitted to burners, inside the burner cock, for adjusting the quantity of gas passed at the prevailing pressure. They do not control the pressure, but only the discharge. Strictly speaking, they should be called Adjusters rather than Regulators, because they merely accommodate the flow of gas, or of air, to the requirement of the incandescent mantle, or the gas fire or cooker burner to which they are attached. They are very useful substitutes for a governor, being inexpensive and capable of giving an excellent result with bunsen burners of all sizes down to the smallest, or "Bijou" inverted lamp, consuming under one cubic foot of gas per hour.

"Bray's Adjuster" was designed for upright incandescent burners, and has been adopted for the boiling rings of cooking stoves. It operates by stopping the flow of gas through one or more of the usual five holes of a burner of the class in question.

The "Nico" Regulator is a needle capable of being pushed forward or withdrawn from a round hole, so as to vary the area of the annular opening for the gas. It was designed for inverted lamps. In company with air adjustment it is very convenient for the purpose.

In any case, the ordinary burner cock must *not* be used to adjust bunsen flames employed for lighting or heating. It should be a standing rule in gas supply work that the fitter of any appliance must adjust and leave the job so as to function properly *with the burner cock turned full on.* This is as near "fool proof" as a gas appliance can be made. It cannot be too strongly insisted upon that the only proper use of the burner cock, as of the main cock, is to turn the supply of gas *on* or *off*, wholly or partially. All adjustment of the gas burners to their proper purpose must be effected otherwise, by means of suitable governors or adjusters. The flames of boiling rings, cooker ovens, &c., must, of course, be reduced by the cocks when less than the full flame is required; but *it should not be possible for the consumer to go wrong by turning the cock full on, whatever the pressure.*

Consumers' Meters and their Fixing.

THE Author feels that he cannot approach the technics of Commercial Gas Measurement in a manner better calculated to place the subject upon a footing of explanation which can be shared by consumers and users of meters, as well as suppliers of gas and their agents, than by reproducing the essential matter of his Popular Lecture on Gas Meters, delivered in connection with the National Gas Congress and Exhibition, 1913. The full title of the lecture was:

"THE CONSTRUCTION, OPERATION, TESTING AND READING OF A GAS METER."

SYNOPSIS OF THE LECTURE:—

Discussion of the Original "Rental System" of Selling Gas—The legal status of the Meter (meter registration only *primâ facie* evidence of amount delivered)—Reasons for the adoption of the Meter System—The objection to the erroneous use of the terms "metre" and "gasometer"—Conditions of satisfactory meter construction and use—First inventor of a gas meter—The "wet" meter—Its advantages, drawbacks, and reasons for the preference given in practice to the "dry" type of meter—Reputation of gas meters—Their fairness—Legal certification—The frequent reading of meter indices advised—The justice of charging meter rent—The puzzle of "Unaccounted-for Gas"—What the meter will not do.

"The sale of gas by measure has been practised for so long a time that "the memory of the oldest inhabitant runneth not to the contrary;" and it requires some effort of thought to conceive of a different system. Yet it is an historical fact that when most of the big gas undertakings now existing began business gas light was supplied by time contracts. As the gas itself was not used for any other purpose than the supply of a certain number of lights, intended to be lighted up regularly at dusk, and extinguished at a specified time every evening, the commercial basis of a contractual obligation could be distinguished without initial difficulty. The arrangement was styled "Gas Rental;" and the term is perpetuated in the revenue accounts of gas undertakings to the present day. The system itself remains in operation for Public Street Gas Lighting contracts; having resisted the attempt, somewhat favoured in certain localities some years ago, to supplant it by what was called the "Average Meter System." It has quite recently been revived in respect to the service of shopkeepers' display lights, which are to be had in many places for an inclusive charge on a time agreement.

In may perhaps be convenient to explain here the precise legal standing of the consumer's meter, as the instrumental factor in an ordinary contract between the supplier and the purchaser of gas for private consumption. In law, the indications of the meter index as to the quantity of gas that has in fact been delivered and must be paid for, are only *primâ facie* evidence; and if the purchaser questions their correctness he has the opportunity, and the onus, of disproving their conclusion. It would be contrary to the equity of English law to assume the infallibility of any mechanical arbiter between buyer and seller, in the absence of personal inspection. Therefore, it is always open to a disputing consumer to have his meter tested by the duly appointed authority; either after removal for the purpose to the Meter Testing Station, or by means of a portable standard meter brought to the premises and placed *in situ* with the impugned article. I will return to this part of my subject later; proceeding now to deal with the reasons for the introduction of the meter system of measuring gas on sale, and the method by which it is carried out.

It does not require detailed argument to prove that the original rental system was essentially defective, and necessarily unsatisfactory to both parties. The first difficulty arose about the pressure of the supply. The quantity of any fluid, including a gaseous one, which will flow in a given time from an orifice opening into the atmosphere depends chiefly for one and the same fluid upon the driving power, or pressure behind it. The primitive gas burners were, of course, all of the simple luminous type, which is merely a hole at the end of the gas pipe; and the size of the flame and its good appearance depended wholly upon the sufficiency and uniformity of the pressure of the supply. Absolute constancy and adequacy of pressure all over the district is an ideal after which gas works' managers have continually striven; but owing to a multiplicity of difficulties which cannot be gone into here it is only approximately realised in everyday working even yet. Naturally, at the beginning of the business it was unattainable. Moreover, whereas the renter of light wanted all the brilliancy and smartness of flame he could get, the suppliers lost by every flame which burnt more gas than it should do at the mean pressure. Besides, the street mains and service pipes were all of such a makeshift character that it was a grave consideration to keep the pressure down to the lowest permissible figure; which commonly meant just on the windward side of a cyclone of complaints. It is a curious survival, such as one not infrequently recognises in old-established rules and regulations, that the minimum pressure of gas in the street mains is still subjected to Parliamentary supervision; although the conditions of supply are altogether different. Again, when the supply of a commodity such as gas is of necessity constantly laid on under pressure, to leave the user and his servants to help themselves to it for any length of time is not a defensible proposition. The vendor cannot have the protection of a proper balance sheet of his working and sales.

Therefore, from the commencement, the gas industry sought a means of selling gas by measure. The difficulties are great in the way of the design and construction of a suitable meter—please note the proper spelling, as a few people persist in spelling it wrongly, as "metre"—which is a different animal. Also, while we are about it, let everybody observe that there is no such thing as a "gasometer." There are gasholders and meters, but no hybrids between them.

A satisfactory gas consumers' meter must satisfy numerous apparently contradictory requirements. It must be (1) reasonably accurate and trustworthy, say, up to the standard of a good watch; (2) it must be durable; (3) it must work with but little driving power, which must also be obtained from the gas; (4) it must measure with equal accuracy the smallest and the largest volume of gas passing through it; (5) it must be reasonably safe in action; (6) it must be fairly immune from fradulent interference; (7) it must not jump, stick, or make a noise; (8) it must be inexpensive; (9) its indications must be easily read, in terms of the commercial measure of the gas. The catalogue is not meant to be exhaustive; but it will do to go on with. Above all it must be susceptible of thorough verification so as to be stampable as a correct measuring instrument, according to the law applying to weights and measures in general.

These being the initial conditions necessary to be fulfilled it is not wonderful that half a century elapsed after the actual introduction of gas supply before a meter was made to pass the tests of experiment and practice. The first attempt was due to the ingenious Samuel Clegg, first engineer of the pioneer gas company, now The Gas Light & Coke Company. He proceeded upon the fairly obvious lines of a pair of bladders, filling and emptying alternately, by the pressure of the entering gas lifting a weight on the bladders, but the difficulty of finding a suitable membrane and others proved insuperable. Then he tried an arrangement of a chambered drum, revolving horizontally in water, but although this appeared to anticipate the "wet" meter, which eventually proved successful, he missed the essential of unoscillating filling and emptying.

It is time to get on with the story, so I must cut the intermediate details and come to the net result. The wet meter was taken in hand by a succession of clever mechanicians—John Malam, Samuel Crosley, and many more, down to Warner and Cowan, in our own times. As a positive measurer of the volume of gas constantly flowing at a steady pressure through the instrument it is perfect. It is therefore employed exclusively when gas has to be measured with the greatest accuracy for scientific or legal purposes. There are no valves in it, the gas being measured as it fills one section after another of the metal drum as they rise out of a level surface of water. Its simplicity renders it inexpensive to construct: there are no friction parts to stick, nor anything to get out of order so long as the material holds together. The revolutions of the drum are registered by a train of wheels indicating the tale of their revolutions on dials, of which each, counting from right to left, is a tenfold multiplier of the one before.

Although the wet meter, as here described, perfectly satisfies the requirements specified, and thereby put the commercial supply of gas upon a sound footing, it has failed to maintain its position in the ordinary service of private consumers of the largest British gas undertakings, and of many others. For over a quarter of a century not a single wet meter has been provided to a consumer by any London or suburban gas company; although this type of gas measurer is regularly used to check the manufacture of gas at their works. The explanation lies in the greater convenience of the alternative type of consumers' meter—called the "dry" meter, which satisfies the requirements of the law and of the business quite as well, and gives less trouble. The fatal drawback to the popularity of the wet meter was its liability to stop working, thereby plunging the consumer's house or shop in darkness, if the water should happen to freeze any cold winter's night. Seeing that this would be just the time when a good supply of gas is most needed the stoppage of the meter would give great annoyance. From the companies' point of view, also, the weakness of the wet meter lay in the necessity for inspection, say, every six weeks, to see to the maintenance of the correct water level; and perhaps at other and irregular intervals, in doubtful cases, to prevent tampering with the water level so as to make the meter register too slow.

Consequently, for one reason and another, the dry type of meter has supplanted the wet—if not altogether throughout the Kingdom, at least so largely as to warrant my devoting my further observations to this form. Meanwhile I beg your attention to certain matters affecting the general system of the supply of gas by meter, which it is desirable should be better known, or at any rate more fully appreciated by the public, in whose interest they have been ordered and are being daily carried into effect.

I am reminded by the Programme that the gas meter has a reputation which has been somewhat blown upon, chiefly by professed humorists. Why this should be is not easy to guess; because, so far as my acquaintance with it extends—and this is not a thing of yesterday—the gas meter has never enjoyed a "past," in the novelist's sense. It therefore seems a little unfair that it should go short of the honour due to a regular legal status respectably borne for upwards of half a century. The Golden Wedding of such helpmeets as gas and the meter ought surely to be an occasion for sinking all ancient scandals, whether true or merely rumoured!

Yet what says the Bard?—"Be thou as chaste as ice, as pure as snow, thou shalt not escape calumny."

Perhaps we may see an explanation of this hoary misunderstanding in the novelty, to a past generation, of a meterage method of telling off anything, which ought not to persist in an age of meters for various purposes—not all so simple as gas measurement.

The law and the science of gas measurement for the supply of private consumers are briefly as follows:—An Act of Parliament was passed in 1859 called the Sale of Gas Act, which defined the legal standard or unit of gas when sold by measure as the Cubic Foot, containing 62.321 pounds avoirdupois weight of distilled or rain water, weighed in air at the temperature of 62° Fahr., and bar. 30 ins. Models of this unit of capacity, made in the form of a bottle, were ordered to be supplied wherever wanted for testing the correctness of meters. No meter can be stamped as a legal measure of gas which is or can be made to be wrong beyond the limits of Two per cent. in favour of the seller, or Three per cent. in favour of the buyer. This is a very high average of accuracy for retail sales by weight or measure.

Never is a meter put into service without the official stamp. Once passed for use a meter does not easily go wrong. It will last a lifetime in a dry and cool situation. So far from robbing the consumer, if a meter does go wrong it must nearly always be in respect of passing gas unmeasured. The modern fashion of pilot-lights for distant ignition of lamps puts a severe tax upon the meter, which is called upon to register, for many hours of every day, a flow of gas amounting to a small fraction of its total capacity. If the outer case of a meter leaks it is unmeasured gas that escapes. Although the proceeding cannot be commended in point of fact meters will bear to be worked far beyond their rated capacity.

It is to be desired that consumers would show a little more interest in their gas meters; instead of vilifying the instrument whenever their own carelessness has resulted in a heavy gas bill. I have already indicated the nature of the situation which a meter should occupy. It is for the company's man who fixes it to see that it is properly placed and connected; but consumers' requirements in this regard are sometimes harsh, and the poor meter has to live where it can.

There was a time when the general practice of charging a rent for the gas meter gave rise, in some places, to complaint; and for many years no such charge was levied within the City of London. Some people used to argue that inasmuch as the butcher or the grocer made no charge for the use of the weights and scales required in their trade, gas ought also to be measured free. The reply to this argument is that if the shopkeeper had to provide a separate set of weights and scales for every customer he would have to charge for them. The cost of metering, including repairs and maintenance, is far from being a negligible quantity; amounting often to upwards of a penny per 1,000 cubic feet on the total sales.

It is impossible to treat of the supply of gas by measure without mentioning the subject—which is occasionally made up into a bugbear by journals in search of a sensation—of " unaccounted-for " gas. Newspapers have stumbled upon this entry in gas undertakings' balance sheets, published in the ordinary course, and have madly endeavoured to make the public's flesh creep by conjuring up a horrid spectre, inflated by all the unaccounted-for gas of years, imagined to be wandering about in the Metropolitan subsoil, waiting for a chance to blow the capital into smithereens, and meanwhile insidiously poisoning us all!

The truth of this matter is that the figure representing what is called Unaccounted-for Gas is largely a mere book entry, required to make up the difference between the output of gas chargeable to the Distribution Department, and the quantity returned as measured by the consumers' meters, estimated as consumed by the public street lamps or under other contract without measurement, etc. There is naturally always a hiatus. There is, of course, an uncertain amount of actual leakage from mains and service pipes, which are of all ages, and buried at various depths underground, the top level of which is sometimes altered in the course of roadmaking and paving operations. The problem of the modern road is as grave for users of the subsoil for pipes, etc., as it is for traffic. I cannot go deeply into this part of the general subject, but it should not be overlooked entirely. The increasing weight and number of road motor vans precludes the hope that modern traffic will prove less damaging to underground property than the old; or that the constant anxiety of the gas distributing engineer for the soundness of his tubes and their fittings will be lessened as time goes on.

Besides the unknown quantity of actual leakage the Unaccounted-for figure covers the "turn of the scale" represented by the advantage of 1 per cent. allowed on the consumer's side of the meter adjustment. It also includes the shrinkage of the gas on cooling to the subsoil temperature, and the bulk of the water vapour condensed out of the gas by the same agency. These elements do not vary much in a particular undertaking, and therefore the study of the unaccounted-for percentage on the output is more intelligible to, and of greater moment to the distributing engineer from one year to another than they can be to the casual panic-monger.

And now, having run over the most prominent points arising from the general consideration of gas meters and their office, it will perhaps be of even greater practical interest to consumers to receive a few hints as to what the gas meter cannot do, and what should not be expected of it. In the first place, the meter, although not perfectly reproducing the character of George Washington, who "couldn't lie," and therefore was truthful by compulsion, in point of fact very rarely does make mistakes. Its customary trustworthiness is materially aided by the regular inspection of its indications by the officer of the suppliers of gas, for the purpose of making out the account; when any unusual figure is, of course, detected. The co-operation of the consumer in thus regularly reading his meter is very desirable, especially where there has ever been any dissatisfaction with the bill. The more often the meter is consulted the less it will be maligned.

Many suspicious consumers have been satisfied by a monthly reading, while the user of a "slot" meter usually regards his meter with the utmost respect.

By regularly inspecting his meter at reasonably frequent intervals the consumer who has to pay the bill will be able to check waste and extravagance in the beginning, which is better than finding them out too late, through the presentation of a staggering gas bill. Especially is this caution to be emphasised upon the adoption of any fresh piece of apparatus, such as a cooker, water circulator, or gas fire. It is far better to insist upon due economy according to the text supplied by the meter than to be everlastingly worrying the household about it in general terms, or trying to catch the burners going wrongfully. It is easy to waste gas—so easy that some good judges reckon that half the average consumption of an ordinary cooking stove will go to no purpose, in heedless hands; and this is where the meter can be a true friend to the householder. Cases are on record of stoves and hot-water circulators, lighted up by the fitter to show the operation, having been left burning full on for the rest of the quarter, night and day, for want of knowledge.

Meters will not pass gas unless there is a burner tap open, or on the rare occurrence of an undetected leak. It is impossible to make the index work merely by putting on extra pressure at the works. Unless the house is to be left unoccupied for a considerable period it is a mistake to shut off the main supply cock at the meter. This should never be done as a regular nightly custom, with the mistaken notion of saving gas or avoiding danger. It prevents the use of flash-lights or watch-lights, and is apt to lead to explosions: because the turner-off does not know whether all the bedroom lights are out or not. Never manipulate the main cock with the idea of reducing pressure, and thereby saving gas. If your district pressure is excessive, which the gas inspector will tell you, have a good pressure governor fixed. It will pay for itself over and over again."

* * * * *

General Description of the "Wet" Consumer's Meter.

The "wet" meter, as remarked in the lecture, is the oldest form of this appliance. Its measuring part is a drum, revolving horizontally on an axle, which carries a worm at one extremity, gearing into a wheel fixed upon a vertical spindle which eventually drives the wheel-train of the index. The accompanying illustration (Fig. 8) shows the arrangement; and also the float which, by falling with the water level, shuts off the gas when the margin of correct measurement is passed.

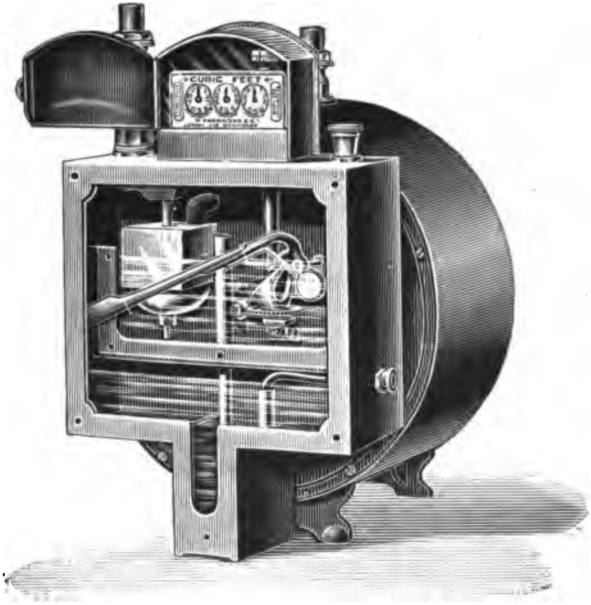


Fig. 8. Compensating Wet Meter, Slow Spoon Principle.

General Description of the Dry Meter.

THIS kind of meter is ordinarily made in a square shape, and although only soldered the cases are very strong. The measuring element is a pair of bellows, with disc faces, which are alternately filled and emptied of gas; and by their horizontal displacement cause eventually a rotary motion of the wheel-train of the index. (Fig. 9.)

The gas is admitted first inside the meter case to the outside of the bellows, so that in the

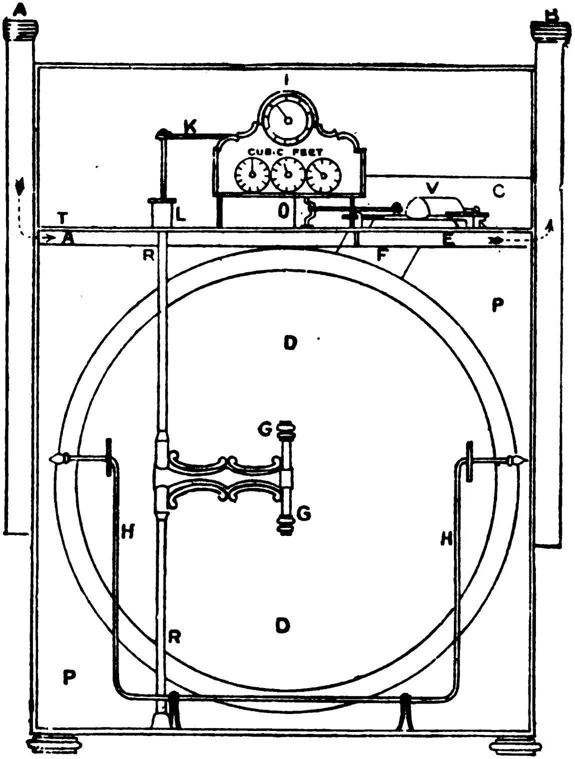
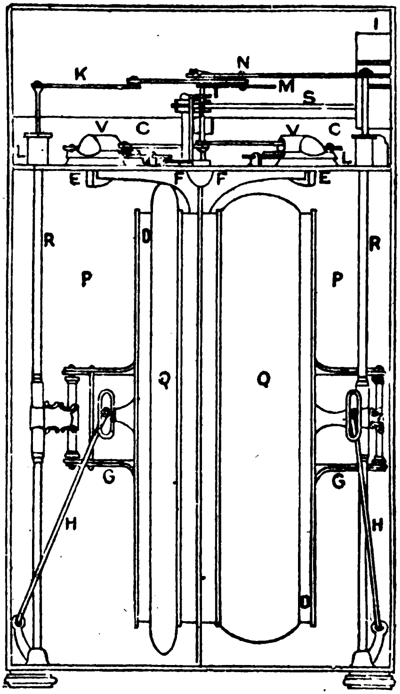


Fig. 9 DRY METER (GEORGE GLOVER).



event of a leak from the case it is unmeasured gas that escapes. The course of the gas through the meter is controlled by slide-valves, similar to the slide valves of a steam engine.

A.—Inlet.
B.—Outlet.
C.—Valve Chamber.
D.D.—Moveable Discs.
E.E.—Outlet pipe from middle ports of slide valves.
F.F.—Pipes connecting outer ports of valves with interior chambers.
G.G.—" T " pieces connecting discs w'th driving rods.
H.H.—Guides to preserve parallel motion of discs.
I.—Index.

K.—Arms connecting driving rods with cranks.
L.L.—Stuffing boxes, to keep gas from escaping round rods, from measuring chamber.
M.—Slotted "tangent" of crank.
N.—Pin in slot of "tangent" to regulate throw.
O.—Crank for opening and closing valves.
P.P.—Exterior Measuring Chambers.
Q.Q.—Interior Measuring Chambers.
R.R.—Driving rods.
S.—Wheel and spindle communicating the revolutions of the crank to the Index.
T.T.—Valve plate.
V.V.—Slide, or plate valves, which admit gas alternately to the interior and exterior Measuring Chambers.

The index of the meter is alike for both kinds, as regards the registering dials; but the small, or testing index, which reads single cubic feet, is different. This, however, is immaterial. The index of a 10-light dry meter is shown in Fig. 10, the small dial at the top having five divisions representing unit feet; so that when the pointer has moved once round this dial it indicates that five cubic feet of gas have passed through the meter.

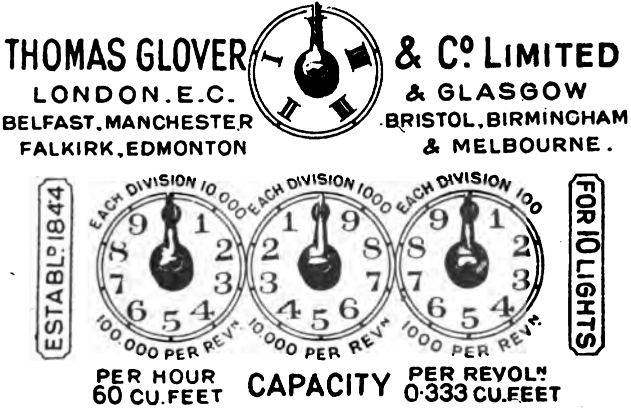


Fig. 10. Index of 10-Light Meter, at "zero."

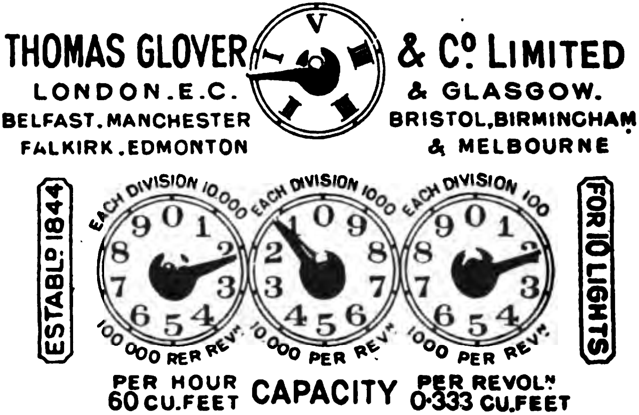


Fig. 11. Same, after passing Gas.

The other three dials are divided into ten. The dial on the right, looking at the face, shows hundreds of cubic feet; which is the smallest quantity charged for. Two ciphers must therefore be added to the indication of the pointer of this dial, which counts 1,000 cubic feet for a complete revolution. By that time the pointer of the next or middle dial will have moved one division, thus counting in thousands. When its pointer has completed a revolution, the pointer on the next, or left-hand dial will have moved one division; thus counting in tens of thousands. Be it noted that only the figures *actually passed* by the pointer are to be counted.

Thus the index in Fig. 10 stands at zero. In the following figure (Fig. 11) the index reads 21,200. Observe that the pointers of the successive dials turn in opposite ways, which is done to simplify the wheel-train and avoid unnecessary friction. Now, deduct the first reading from the second,

21,200
00,000

21,200

and this will be the quantity of gas passed between the two inspections.

The sizes of consumers' meters are graded by the number of "lights" supposed to be supplied, as 5-light, 10-light, 20-light and so on; each "light" representing six cubic feet per hour passed. Meters should not be continuously overloaded, although they will pass a considerable excess of gas on an emergency.

"Prepayment" and "Slot" Meters.

FOR some time past, in certain gas supply districts, the policy of cash payments by consumers, either at short intervals or in advance has been in operation; but the most considerable step in this direction was made by the late Mr. W. A. Valon, at Ramsgate, with his Prepayment Meter. There were at the time numerous small dwellings in Ramsgate, as elsewhere, which had not been supplied with gas owing to the expense of the necessary fittings, and the objection of the occupiers to run long bills. The difficulty was overcome by the Corporation agreeing to fit up such premises without charge, and installing the Valon meter, through which any agreed quantity of gas can be supplied, the meter automatically stopping the supply as soon as the quantity paid for has been consumed.

The index of the meter has an additional hand, which is called the "stop hand." This stop hand can be turned forwards, but not backwards, by a loose key. It is in connection with a disc or clutch and pin, whereby when the registering pointer has arrived at a position coincidental with the stop hand, the stop action takes effect and the meter ceases to pass gas. Although this device has not come into such extensive use as the "slot" meter, it possesses certain superior advantages to the latter, especially where the scale of consumption is somewhat large. Thus, it is popular with lodging-house keepers, etc., whose consumption varies considerably according to circumstances, as any quantity of gas can be booked in advance, and there is no trouble about a sudden shutting off.

The "slot" meter has undoubtedly proved itself to be one of the greatest boons of the century to the small householder, inasmuch as it has placed the economy, comfort, and safety of gas lighting and cooking within the reach of "the million" who would otherwise have had to go without. There are numerous patterns of the appliance, which is simply an addition to the ordinary consumer's meter, leaving the measuring function of the instrument untouched. It comprises a mechanical movement in which a coin forms a link, which sets open by a certain space an extra valve within the meter, which the movement of the meter itself tends to shut when the quantity of gas paid for has passed. The coins are deposited in a locked box from which they are collected by the agent of the gas authority, any difference between the money found and the amount due according to the registration of the meter being made up by or refunded to the consumer, as the case may be.

The following descriptions of typical slot meter movements are taken from a paper by Mr. T. S. F. Gibson, read before the Junior Institution of Engineers.

"Many slot meters have been put on the market in which the flow of gas has to be stopped by holding the meter registration mechanism and relying on the meter valves for tightness. This is not desirable, as it tends to strain the meter as a measuring apparatus. There are several meters in which the coin has not been used as a gag but simply as a weight on the end of a lever. This movement does not appear to the author as positive enough for the purpose.

"In the design of a coin freed mechanism for a gas meter, the following details must receive careful attention:—First, there must be some arrangement of fraud prevention to deal with such devices as a coin on a string, a piece of wire inserted through the slot, stopping the mechanism half-way and turning it backwards and forwards; also the slot must be of such a size that coins, which are bent so much that they would not work the gear but only jamb, are rejected. Provision must be made, so that when the coin has done its work in moving the gear it can be discharged only into the money box.

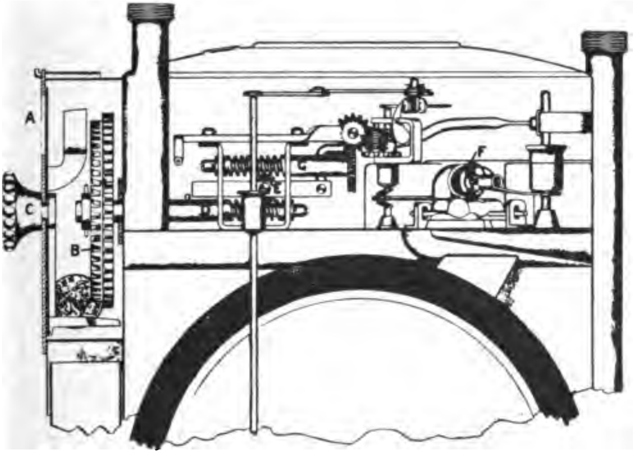


Fig. 12. A "Slot" Meter Attachment.

"Referring to Fig. 12, the coin is inserted through a slot in the plate A into the slotted arm B, and so forms a connection between the handle C and wheel D. When the handle has been turned to its fullest extent, the coin drops free owing to the arm B coming into contact with a stop E. The arm B carries with it a covering plate, so that until it is returned to its normal position no other coin can be inserted. The handle cannot be turned in the reverse direction when the coin is in, owing to the action of a rachet pawl F acting on the wheel D, nor can it be turned right round, owing to the stop. The plate A is removable, and contains holes round its periphery, so that the angle swept by the arm B is variable, thus giving the necessary adjustment for variation of volume of gas supplied per coin.

"There are two distinct motions to be considered for the actuating of the valve; one, the action of the coin, and the other the action of the meter. These two motions have to be allowed for in such a manner that although they are contrary to each other they may go on either separately, together or alternately.

"When the coin wheel in Fig. 12 is turned, the spindle D inside the meter revolves and the worm in which it terminates imparts a rotatary motion to the worm wheel E, which in turn moves G, and this is in connection with the gas valve F; which is accordingly opened a corresponding distance. When gas is passing, the action is reversed. A worm-wheel geared with the index mechanism drives the spindle G and closes the valve. It is apparent that both spindles A and E can revolve together or alternately without damage to the gear, and neither can produce motion in the other.

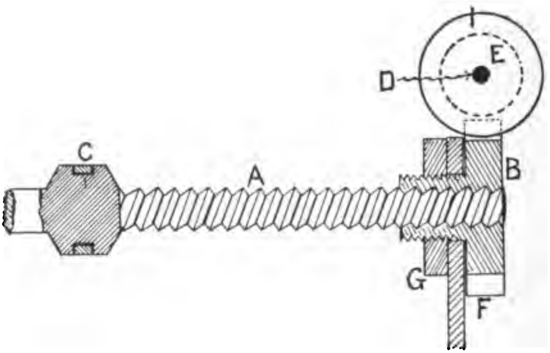


Fig. 13. Another "Slot" Meter Movement.

"Fig. 13 shows a solution by means of a tied nut. The spindle A is rotated by the coin mechanism, and in so doing gets rectilineal motion from the nut B, and carries forward a fork C, which opens the valve; this is returned to its seat by the action of the meter through the spindle D and worm E acting on the worm-wheel F, which is cut on the outside of the nut B; this nut is held by the screwed and pinned collar G from moving laterally, consequently the spindle A is returned to its original position, carrying ths fork C back and closing the valve.

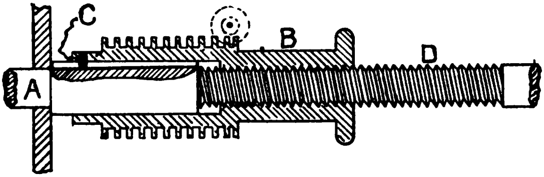


Fig. 14. "Slot" Meter Attachment.

"In Fig. 14 the spindle A is rotated by the coin action, and so rotates and advances the long sleeve nut B which can slide on the spindle, but cannot rotate owing to the feather and fearther-way C; the movement of the sleeve nut opens a valve by means of a lever (not shown in the diagram), and the reverse motion is by the rotation of the spindle D, which is revolved by the meter, but cannot move longitudinally; consequently the long sleeve nut B has to slide back upon the spindle A and so closes the valve. The small wheel on the top of the sleeve nut is for actuating a register showing the amount of gas paid for.

"When the gas purchased has been nearly all delivered, the gear for shutting down the valve should do this operation slowly enough to give the consumer reasonable warning that the supply is about to cease, and it is time he again fed the meter. In the case of the gears illustrated in Figs. 13 and 14, this is done by the shape of the lever actuated. In both these mechanisms the valve is practically open to its full extent by the inserting of the first coin, and is kept in this position by the lever while the whole of the gas paid for is passing through.

"It must be possible for the consumer to insert a definite number of coins not less than twelve, and there should be a register showing clearly how many coins have been passed into the meter, but for which the meter has made no return, i.e., how much gas has been paid for but not delivered.

"This is very important, not only from the consumer's point of view of knowing just where he stands, but also from the fact that it is not desirable to work a slot meter always on the first coin, as it is seldom that the meter passes the same amount of gas for the first coin as it does per coin for say six coins put in all at once, the reason being that the backlash of the gear and the compression of the valve face (the valve faces are generally made of soft material so as to ensure tightness) have to be taken up before the motion starts, and this must be always done by the first coin. Should a consumer always work on the first coin, it will be found that the amount of cash in the box is above the value of the gas shown by the index of the meter, and although consumers are always very pleased to have a return from the meter it is not desirable to be knowingly inaccurate.

"The arrangement for changing the volume of gas delivered for the coin must be of such simple construction that it is easily reached and operated when the meter is in position, and on no account should it be necessary to break the connections to do so. One simple arrangement has been referred to in relation to Fig. 12; another and very popular method is to change the gear wheels themselves. It is advisable to always seal the arrangements so that no one can alter the volume except the specially appointed officers of the Company.

"The mechanism should preferably be attached to the side rather than the top of the meter, as the largest dimension of the gas meter proper is its vertical one, and it is generally easier to find positions when there is room laterally and where the head room cannot be got. There can be no rule laid down here, as the positions in which these meters are fixed vary.

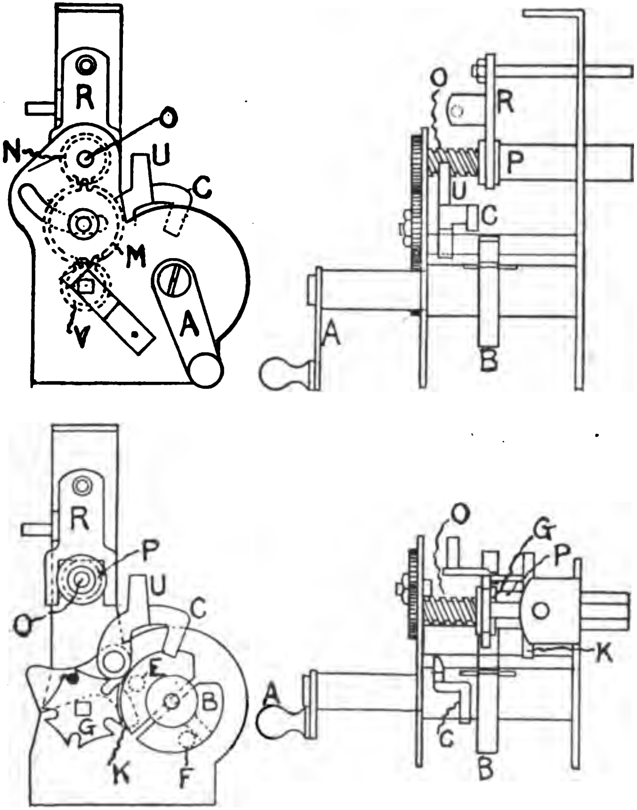


Fig. 15. "Slot" Meter Coin Mechanism.

"Fig 15 illustrates a complete compact mechanism which is attached to the side of the meter. The handle A turns the coin carrier B, which receives the coin through a slot. The coin carrier has a limited stroke between two stops E and F, and works in the scollops of a scolloped wheel G, so that the wheel G cannot turn except when the coin carrier is at a predetermined position of its stroke. When the coin carrier receives the coin the first movement causes the coin to lift a pawl C, and, immediately the coin passes the pawl drops and the carrier cannot return to the slot position. This pawl C also serves the purpose of making it impossible to introduce more coins than the meter is design to take, for when the total number of coins are in the meter an arm U comes in contact with the portion of the nut P (to be described later), so that the pawl cannot lift, and therefore the coin carrier cannot revolve.

"When the coin carrier has passed this pawl, the edge of the coin lifts another pawl K, the object of which is to prevent the wheel G from being revolved when the coin carrier is in such a position that it could otherwise be made to do so, say, with a wire inserted through the slot or such means. Having lifted this second pawl, the arm of which is long enough to ensure its being held up during the rest of the stroke, the coin engages in a slot in the scolloped wheel G, and as at this time the high points of the scollops in G are opposite a depression in the coin carrier wheel, it can revolve by the further movement of the handle until just before the coin carrier comes in contact with the stop F, the coin frees itself and drops into the money box; the weight of the handle then brings the coin carrier back under the slot ready to receive another coin.

"The wheel G is mounted on a spindle having a square end which carries a pinion V; this pinion is used as a change wheel and is held on the spindle by a pivoted Z piece, and gears with a spur wheel M, the axis of which it is possible to slide backwards and forwards in a curved slot about the centre of the wheel N into which it gears, so as to allow larger or smaller pinions to be fitted on the square end of the spindle carrying the wheel G, and yet keep the gearing in proper mesh. The wheel N is mounted on the end of the spindle O, which is chased with a multiple square thread so as to give the nut P a convenient travel; this nut carries with it a fork R, which has two arms, one of which opens the valve through a lever and the other moves a register of the coins, showing the number for which gas has not been supplied. The nut P also has a long sleeve which enters the meter; this sleeve is slotted throughout its length, so that a spindle driven through gear by the meter can be coupled to it by means of a small pin. The meter motion is so designed that in revolving the nut by means of the sleeve, it travels along the spindle O to its original position and so closes the valve.

"The whole apparatus must work smoothly and without any tendency to bind or slip, as, although the meter is powerful enough without much loss of pressure between inlet and outlet to move a most refractory mechanism, still there is always a danger of jumping lights. The gear for closing the valve when the gas paid for has been delivered, generally the reverse of the coin-freed gear, must be so attached to the registration gear of the meter that it will not interfere with it in the event of the valve not being tight when home, and so allowing gas to pass and drive the meter. It is desirable that a weak place should be left in the coin-freed mechanism, so that in the case of a breakdown the registration shall continue uninterrupted. It must be remembered that a gas meter (dry) is nothing more than a double acting two-cylinder engine having, in the three-light size, pistons of a diameter of about 8 inches, and consequently even at low pressure at which gas is distributed (2 or 3 inches of water) a very powerful machine, and that should the gear jamb when the power is being supplied something has to break, and it is most important that it shall not be anything in the meter itself as a measuring machine.

"Owing to the number of robberies from slot meters lately, the money boxes have received a great deal of attention. In the author's opinion, although it is very important to have a strong box on the meter, its limit of strength must depend almost entirely on the cost considered allowable for this item; and it is not at all desirable to have a first-class safe fixed up against a tin gas meter. In fact, the cost must be regarded as an insurance premium against robbery, and should be worked out on that basis. Another way to consider the matter is to make the box just strong enough to give the would-be thief sufficient trouble to make him come to the conclusion that it is not worth his while working hard to steal a problematic amount. It is important that the mechanism be so attached to the meter that the authorities for stamping are able to stamp, etc., the meter as a measuring instrument, and yet to leave the coin-freed mechanism so that it can be afterwards opened and adjusted, and even small repairs made by the Gas Company, without breaking the official seal."

"Facility must be provided for price changing. The alteration must be easily made without breaking any gas joint. Even so, it is a costly proceeding where these meters are numbered by thousands, and in practice it is commonly found preferable to return the excess payment when it is of small amount, as would be the case where there had been a reduction of price of a penny or twopence per 1,000 cubic feet."

"From enquiries, the author finds that nearly all the mechanical troubles of slot meters are due to leaky valves; many inventors have recognised this, and have brought out ingenious devices by means of which they hope to make the valves always absolutely tight."

Repairing and Testing Meters.

An important part of gas distribution work is concerned with the repair and testing of meters. When a meter is removed from its position on the consumer's premises, according to the routine followed in such proceedings, it must be immediately corked up and conveyed as it is to the receiving depôt. Here the water is emptied out of a wet meter; and all dry meters are uncorked and the top removed, a hole cut in each side of the bottom, and the meter stood at an angle to drain.

In due course it is opened up, overhauled, and the necessary repairs, if any, seen to. The slide valves are re-ground upon their seats with powdered turkey stone; the leathers re-oiled with almond oil, and the stuffing-boxes re-packed with oiled Berlin wool.

Then the repaired meter is tested for soundness and for working with a small light, to one-fortieth and also at one-twentieth of its rated capacity; afterwards at its full capacity. The correction of registration is by adjusting the throw of the tangent rods which convert the reciprocating motion of the bellows into the rotary motion communicated to the index train.

The test for measurement is by passing gas from a graduated holder through the meter.

The principle is as follows:—If the scale on the holder reads 98 and the meter 100, the meter appears fast by two.

Then, as 98 : 2 : : 100 : 2.04

which is the true percentage *fast*. The meter is sent back.

Or the meter reads 100 and the holder 102—the meter appears slow by two.

Then, as 102 : 2 : : 100 : 1.96 true percentage *slow*. It is passed for further test by the local authority, who will affix to the lid the official seal, without which no meter can be issued for public use.

Very rarely examples have been found of wrong indices in meters. That is, a 5-light meter with a 10-light meter index; or contrariwise, a 10-light meter with a 5-light index. The former will register 150 per cent. fast, and the latter 60 per cent. slow.

If on testing a meter, the registration of which is disputed, it is found to register wrongly, the correction of the account for gas actually consumed is made by computing the quantity it *ought* to have registered as a percentage of what it *did* register. Thus, for example, if a meter has registered 40 cubic feet, whereas 100 cubic feet have passed, the difference, 100—40=60 is 150 per cent. on 40; and this is the quantity to be added. On the other hand, if 100 cubic feet have been registered and only 40 cubic feet actually passed, then 60 per cent. must be deducted from the alleged consumption.

There is no statutory prescription of the size of meter which a consumer may demand, provided that the prospective hourly consumption is not in excess of the capacity of the meter as "marked on the outside thereof." When meter rent is not charged, however, it is probable that the gas authority would be held to be justified in refusing to provide a meter largely beyond the necessity of the ordinary consumption, as a "stand-by" against the failure of electric light. Consumers are at liberty to find their own meters; but no meter may be connected or disconnected from a live gas service pipe without 24 hours' notice to the undertakers.

This provision is very important in regard to the danger of interfering with the service pipe. Also, it is very necessary that a meter, immediately after being disconnected from the service pipe, should be tightly corked up; as an explosive mixture of gas and air otherwise forms in its interior.

Meters should never be allowed to stand upon the floor, but should be placed upon a special shelf to themselves. They should not be exposed to extremes of heat or cold, or to damp. If the interior piping falls towards the meter a drip-leg must be inserted near the outlet connection to collect any liquid condensation. Sufficient room must be allowed for the meter and its connections, and (especially in the case of prepayment meters) it should be conveniently accessible. No part of the meter case is to be in contact with a wall.

In the case of large meters required for mills, workshops and large establishments in general, a special brick-built meter house apart from the main building should be provided. For very large consumptions wet meters are to be recommended.

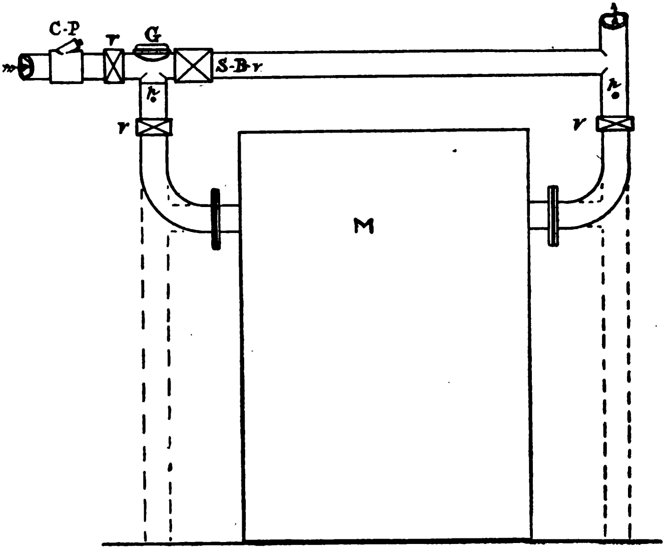


Fig. 16. Connections for a Large Meter; 150-Light and upwards.

M.—Meter. S.B.V.—Sealed By-pass Cock. C.P.—Clearing plug. *p.p.*—testing plugs. V.V.—Cocks. The dotted lines show blind continuations of the inlet and outlet pipes, to take their weight, if required. G.—Service Governor (when required—or, preferably, on the service side of main cock).

In connecting up small and medium-sized meters the best practice is to make the connection between the pipe and the meter with a widely-bent lead pipe of proper weight, and soldered union couplings.

In making the solder-joint between the lead pipe and the union lining the lead must be opened out and worked over the lining. The screw cap-and-lining joint should be made with a greased leather washer, hand-tight only.

Meters of the 100-light size and upwards are also made with flange connections. The drawing (Fig. 16) shows how a large dry meter should be connected.

"Discount" and "Cash" Meters.

HOTEL visitors, lodgers in furnished apartments, and others find a great convenience in the use for their private requirements of subsidiary meters. These instruments are inferential in action, and are not stamped as legal measures for the sale of gas; but are quite accurate for the service of gas fires, baths, or lodgers' cookers. They are made to read either in cubic feet, or in money adjusted to local rates. These "Rotary Meters" are also to be recommended as checks upon the consumption of large gas cooking apparatus where extravagance is suspected.

[NOTE.—Water drawn off from meters or from pipe "syphons" should not be poured down the drains, but conveyed in closed tanks to the gas works for disposal.]

Lighting Fittings: Indoor.

THE character of indoor gas light fittings has been almost revolutionized by necessary adaptation to the requirements of the incandescent type of illuminating burners.

The ordinary and usual fittings for interior gas lighting by means of flat flame burners chiefly comprised "pendants" and wall brackets, mostly jointed and movable. The ceiling pendants were commonly of the "hydraulic seal" pattern, with counterbalance weights; smaller single-light pendants being of the "cork-slide" variety. Only shop and staircase pendants, being longer and heavier, were of fixed length, suspended from a ball-and-socket joint. Brackets were usually jointed, either singly or with two jointed arms.

The superior lighting power and range of the incandescent mantle rendered movable fittings of less importance, while a steadier support became necessary. Consequently, fixed, rather short stiff brackets gradually supplanted the jointed ones; and the absence of the joint also encouraged a greater lightness of construction and more freedom of design. Thus the advantages of greater safety and better appearance were amongst the incidental gains of the new method of lighting. The same operation applies to the pendants. The old, unsafe hydraulic seal is unsuited to the higher gas pressures; and is generally condemned unless converted into a gas-tight fitting by removal of the inner tube and screwing the outer tube into a ball-and-socket connection. (This conversion should be made compulsory everywhere. It costs only a few shillings.)

A new order of pendants came into existence, specially adapted to the upright or inverted patterns of incandescent burners. Adjustability in the vertical sense in secured in a variety of ways. For workshop purposes suspension of the lamp is combined with "anti-vibration" fittings in many styles, combining flexibility and steadiness in a satisfactory degree.

Amongst the most useful of the old-fashioned internal fittings which lend themselves to adaptations to incandescent lights, must be included the "sun burners" and "regenerative ventilating lamps." Good examples of these fittings are easily converted to the new principle; with, of course, a considerable gain of light.

No gas light should be fixed within 2ft. 6in. vertical distance of a wooden overhead construction, without a metal protection properly attached to the underside of the latter.

The problem of the action of gas lights upon ceilings is a very important and difficult one. The dirtying of ceilings over burners is the gravest objection to gas lighting entertained by public opinion; and not nearly enough attention is ordinarily given to the complaint or to means of mitigating the evil.

In the first place the facts should be clearly understood. The cause of the darkening of ceilings over gas burners is not the bringing in of dirt with or by the gas; nor is it usually due to the deposition of soot from the flame, since such flames very rarely smoke. It is really a particular case of a general order of phenomena, invariably produced when fixed sources of heat are introduced into interiors filled with the dusty atmosphere of towns. The convection currents rising from such sources carry up to the ceiling the dust with which they are laden, which sticks to and in course of time forms a dark brown coating upon the plaster, paper, or paint. Steam heating radiators or hot water pipes will do the same. So also will incandescent electric lamps.

In the case of gas lights, the action is intensified by several contributing processes. Of these the most effective is the rapidity of the ascending current, which on other accounts has a distinct hygienic value, as contributing to the circulation of the air of the room and preventing "down draughts." The dust is burnt in the flame, which therefore darkens while sterilizing it. The products of gas combustion contain much water vapour; which causes the charred dust particles to adhere to the ceiling. Really, therefore, apart from the appearance, the action of gas burners in such interiors is sanitary and conducive to comfort.

(In this connection it may be remarked that gas lights have in numerous instances been restored in churches with lofty, open roofs, which had been lighted electrically, in order to keep the atmosphere in the upper region warm, and so prevent the descent of foul air chilled by contact with the cold roof.)

At the same time it behoves gas fitters to respect the popular sentiment, and do all that is possible to prevent the complaint arising. For this reason inverted lamps with devices for scattering the combusion products horizontally are preferable to upright burners, for low-ceilinged apartments. The effect of all such devices, whether forming part of the lamp, or in the separate form of "consumers," should be carefully observed, and the best for the purpose used systematically.

Distance Ignition.

THE chief novelty brought into the practice of interior lighting fitting with the incandescent principle was ignition of the gas from a distance. Previously, distant ignition was only employed in particular cases of large lights in lofty halls, railway stations, etc. The popularity of the "tumbler switch" for electric lighting directed attention to the advantages of providing a similar convenience for gas burners generally; thus superseding the striking of matches for the purpose.

The mantle lends itself to the method of "self-ignition" by the heat produced when platinum "sponge" or "black" is exposed to the action of the hydrogen of the gas, which it absorbs so rapidly that a temperature sufficient to ignite the gas is attained. The preparation of platinum is suspended over the mantle in an upright burner, or applied as a spot upon the mantle itself. Although in a dry climate this device may answer its purpose, it has never retained favour long in the humid atmosphere of the British Isles, in which the action soon becomes too sluggish.

A "pyrophoric" attachment for igniting gas by sparks struck from a cerium and steel alloy has been tried with small success, the operation being too jarring for the mantle.

The only other effectual distance method of igniting gas without a flash-light is by the electric system known by the name of the "Telephos."

In the "Telephos" lighter the ignition is effected by the momentary incandescence of a fine platinum wire, which in the case of an upright burner acts directly upon the gas and air supply to the mantle, and in the case of an inverted lamp first ignites a "spit-fire" jet. It is particularly to be noted that the ignition is *not* by a spark, which latter is unreliable. Absolute safety is claimed for this system of ignition, inasmuch as the electric current, which is supplied from a dry battery, first passes through a coil which opens the gasway to the burner, and therefore if the igniter should be out of service no current can pass. These igniters are renewable at small cost. An "emergency pull" allows the gas to be turned on by hand for lighting with a taper in the ordinary way.

Against the first cost of "Telephos" ignition must be set the saving of pilot light consumption, which is rarely less than from one-tenth to one-eighth of a cubic foot per hour.

"Pilot light" distance ignition can be effected in a variety of ways. Simply lowering the gas supply by shutting off the main cock and keeping enough gas going through a small by-pass is, in a sense, distant lighting; but incandescent burners in general do not bear turning down. Bray's upright burner is the least liable to light back in this way.

Usually, a separate pilot light of straight gas is preferred for this purpose. In the case of extensive lines of large piping, Sugg's mercury seal is used to prevent emptying the pipes between lighting periods. Where a sudden wave of gas in the pipes from the simultaneous opening or shutting of a large number of burners is to be expected (as in theatrical stage lighting), a separate supply must be run to the pilots.

There are several serviceable systems of distance lighting which can be conveniently arranged for in the case of new pipe connections; but the one most generally adopted for existing lights at a moderate distance is the "Pneumatic," in which a small air pipe runs from a wall-button to a sliding piston at the burner which opens or shuts the main gasway. Care must be taken in running the air pipe to avoid kinks, and the piston may need occasional lubrication with blacklead only.

The Internal Piping of Houses for Gas.

THE material now almost exclusively used for internal gas piping is wrought iron tubing, with the standard fittings that go with it. The chief tools required for working it are pipe tongs, "foot-print" wrenches, stocks and dies for forming the standard "gas thread" screws, pipe cutters, taps (plug and taper), pipe vice; and for shop use and on big jobs, pipe bending machines.

These tools and materials are conveniently carried upon hand trucks specially designed for the purpose. (Fig. 17).

The chief points of good barrel work, after the initial selection of sound, well-made tubes and fittings, are clean-cut screw-threads, straight and true, neither too long nor too short, with a good hold in the socket. Obstructions sometimes occur in the tubing, so that it is important to see or blow through every piece before connecting it up in place. All tube and fittings should be perfectly cylindrical, showing no ribs, flat places, nor a conspicuous weld. Internally they should be quite smooth. Sharp elbows are not to be used.

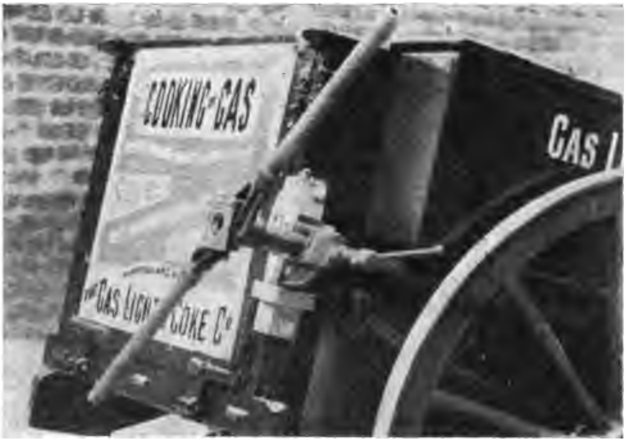


Fig. 17. FITTER'S HAND-TRUCK, WITH "SAMSON" ATTACHMENT.

Minimum weight per foot run of wrought iron gas tubing for internal fittings:—

Dia. ins.	Lbs. ozs.	Dia. ins.	Lbs. ozs.
¼	0 6½	1¼	2 10
⅜	0 9½	1½	3 2
½	0 14	2	4 6½
¾	1 5	3	6 14½
1	1 15		

Formerly the material called "composition (compo.)" was much used for internal gas fitting, especially where the piping had to be put into premises already built. It is lead tube drawn thin and covered with a skin-coating of tin to render it gas tight. The use of such piping for permanent work is not now considered good practice, and owing to the high price of tin the quality of the material is not likely to be maintained. There is no standard of quality for it. Even for temporary purposes the armoured flexible tubing has superseded it.

Where internal gas piping shows, in places requiring special neatness of appearance, as for connecting a gas pipe upon a tiled hearth, brass tube should be used.

Various public authorities and gas undertakings have formulated Rules and Regulations intended to ensure good work and public safety in regard to internal gas fitting. Before planning any job of the kind, therefore, it is necessary to ascertain and conform to the local requirements, if any.

In a general way the following points emerge from a survey of numerous prescriptions in this regard :—

No unnecessary length of service pipe is permitted inside the building. The meter must be as close to an outside wall as convenient. Meter connections must be of the full size of the couplings; and an outlet of the proper size must be left for the cooker, hot water circulator, or geyser. Separate connections must be provided for this class of apparatus, of the full size of the inlets.

No pipe shall support any weight (except that of lighting apparatus), or be pinched in any way. All piping must be properly laid and fastened to prevent becoming trapped; and must if practicable cross over joists or beams, not underneath them. If possible pipe must be run lengthwise of joists; but if it is necessary to cross them, this should be done along a line underneath the second flooring board from the joists' bearing end. Joists are not to be notched deeper than is necessary to cover the pipe; unless it is absolutely essential to cut across a joist near the centre of its span, when the correct procedure is to cut a slot deep enough for the pipe to drop into and allow space over it to wedge the timber up solid again.

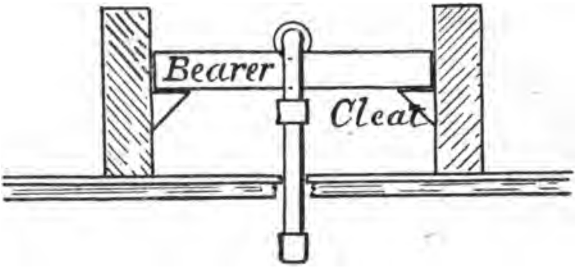


Fig. 18. Ceiling Connection for Pendant.

Flooring boards removed for running pipes underneath must be screwed down again with greased screws, not nailed. Pendants must be suspended in the manner shown by the drawing (Fig. 18). No smaller pipe than $\frac{3}{8}$in. must be laid underneath flooring boards. All open points must be plugged with iron plugs until the fittings are fixed. No burner connection may open less than 3ft. below any ceiling or woodwork; unless a proper protecting shield is fixed, when the distance must not be less than 18ins. No burner connections shall be allowed underneath water tanks, behind doors, or within 4ft. of any meter.

In case of any addition to or extension of old piping being required, if this is wrought iron a sufficient piece of straight pipe shall be cut out, and the connection restored by means of a long screw with right and left hand couplings. If the old pipe is of lead or compo, a proper brass connection shall be used. No soldering to old work shall be permitted. Care must be observed in all such cases that the old tubing is of sufficient capacity to carry the additional supply.

In carcassing buildings the piping to every floor should be tested as completed under a gauge pressure of six inches of water; which should stand for five minutes. If gas is available it should be used for testing. The same test should be applied after completing any job calling for interference with the old work. Fitters after completing any small job of connection with a live gas supply, in which the gauge test for soundness is inapplicable, will always try their work with a light, passing the hand carefully over it in order to detect a "blue" flame.

The general planning of internal gas piping will be governed as to the lengths and sizes of pipes by Table II. The accompanying plan illustrates an example of the complete fitting up (in accordance with Table II) of a dwelling house of the size that would be rented at from £35 to £45 a year, in a Metropolitan residential suburb (Fig. 19).

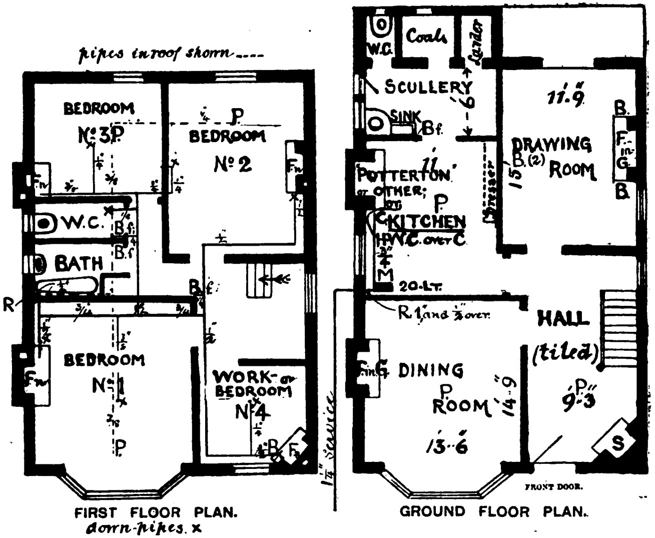


Fig. 19. Gas Piping and Fitting Plan for Residence.

Explanatory Notes.

In a good plan of gaspiping, there is the strictest economy of length consistent with reaching the points;

which is secured in this example by running the bulk of the piping at the first-floor level, dropping down to all ground-floor points. There is no pipe underneath the ground-floor. The Meter (M) and "Riser" (R) should be in the middle of the system; the former easily accessible for indexing. It stands upon a shelf in the kitchen, with a short length of ¾in. pipe to the Cooker (C). The Riser (R), 1 inch, ascends straight to the upper floor, and is tee'd off to ¾in., which runs to the tee on the landing, outside the No. 1 bedroom door. All mixed Fire and Lighting Points are fed off this level by ½in. pipes, reduced to ⅜in. for single fires, and generally for all long lengths leading to lighting points under flooring. Dropping pipes to ground-floor fires are all ½in. The Riser is continued up to the roof level in ½in., and the supply at this level to the Bedroom Pendants (P) is in ⅜in. Single light points off larger pipe are in ¼in. In running pipe it is important to avoid cutting across joists, which usually run from front to back. Crossings should therefore be made underneath the second flooring-board from the bearing-wall of the joists, where the cutting will not weaken the joists. Pipes should wherever possible be run underneath the flooring of passages, and enter rooms at the doorways. Carcassing must be tested for soundness under 6in. pressure for 5 minutes, floor by floor, as the work proceeds; and all points left securely plugged.

The Lighting Scheme comprises the following fittings:—

Hall, 1 Pendant Lantern, with "Bray" Upright burner and pneumatic switch; Dining Room, "Surprise" or "Hanwell" Pendant, with inverted lamp; Drawing Room, 1 double and two single Brackets with Nico "Bijous"; Kitchen, 1 short stiff Pendant, with inverted lamp in half-opal globe; Scullery, stiff Bracket (B), with open flat-flame, No. 5 Economiser upon No. 0 or No. 1 Regulator; Landing, stiff Bracket, with Breeden's pilot, No. 5 upon No. 0 or No. 1;

Bath Room and W.C., stiff Bracket, with Breeden's pilot, No. 5 upon No. 0 or No. 1; Bedrooms Nos. 1, 2, 3, stiff short Pendants (P), with inverted lamps; Bedroom No. 4, Bracket with same.

There will be " Fires " in the Dining and Drawing room grates, with duplex cocks. A Warm-Air Stove (S) of approved pattern, will be most suitable for the Hall. " Nursery " pattern fires for upstair rooms, 30 ft. and 20 ft., according to size of room. Potterton's Combination "Queen" Cooker for choice; or " Advance " Cooker, and Hot Water Circulator. (A suitable coke-fired Boiler, with adequate Hot Water Storage Cylinder, might be recommended in this combination.)

On the Combustion of Gas.

In order to understand the operation of gas burners it is necessary to have a good working knowledge of the processes of combustion in general, and of flaming combustion—the way that gas burns—in particular.

Burning, or combustion, means the union, with the production of sensible heat, of certain elements of the earth's substance with the oxygen of the atmosphere. When the production of heat or light is intended the combustible chosen for the purpose is classified as fuel. Fuels are of different kinds and forms and qualities. Commercial fuels include solids (coal, coke, wood or peat, fatty substances); fluids (oils and spirits); and gases, of which we are only concerned with one—town gas.

The chemical bases of fuels are the combustible elements—Carbon (C) and Hydrogen (H_2); whose complete union with Oxygen (O) forms the inert residual compounds, carbon dioxide (CO_2), and water H_2O).

The energy of combustion of fuels varies according to their richness in these combustibles, separate or in combination, in proportion to their other and incombustible components; and also according to their physical character, which may assist or hinder the process of union of the combustible portion with the atmospheric oxygen.

Fuel in the form of gas is obviously in the most convenient state for rapid and complete combustion, inasmuch as combustibles in the less perfect states of solid or fluid matter require to be gasified at their point of ignition, before they can combine with the oxygen of the atmosphere, and this process of conversion calls for careful attention and involves a considerable loss of energy.

Combustion can only go on where there is contact between combustible and oxygen, and the action requires a certain temperature to start it which is usually considerably higher than the normal atmospheric temperature. Under some conditions, however, this elevation of starting temperature or *ignition* is not requisite, because the combining elements have sufficient affinity to unite without external inducement, in which case the combustion is said to be *spontaneous*.

On the other extreme, some combustions require a higher temperature to start them than they are able to maintain by themselves, in which case they cease directly the ignition temperature is withdrawn. Thus the nitrogen of the atmosphere burns with its accompanying oxygen to nitric acid in the presence of the electric spark; but the combustion will not propagate itself.

Combustibles are only classified as fuels when they burn readily enough to keep alight until all their combustible portion is consumed away, with the production of sensible heat of a useful degree of intensity. The rapidity of combustion varies according to the activity of the union of the combustible with the necessary amount of oxygen.

Oxygen exists in the atmosphere normally in the proportion of about one-fifth part, by volume, to four-fifths of nitrogen, the latter being an inert gas in regard to combustion. It not only dilutes the oxygen with which it is in company, but it also absorbs a large proportion of the heat resulting from the union of the oxygen with the combustible.

Consequently upon the presence of nitrogen, the action of ordinary combustion in the air is much slower and less intense than it would be with pure oxygen. This action can be hurried up within certain limits by forcing the air supply to the fuel; or by sub-dividing and mixing the latter with a volume of air containing sufficient oxygen to unite with the combustible immediately, when the resultant combustion is said to be *explosive*, and the effect an *explosion*.

When the fuel is already in the gaseous form it can easily be burnt explosively by mixing it at the ordinary temperature with the necessary proportion of air and igniting the mixture. Even so, the operation of explosive burning is one of degree. Any excess or insufficiency of air affects the speed, or violence, of the explosion; until the union becomes normal burning or the fire goes out.

The comparative safety of a gaseous combustible is a matter of the extent of the margin between the conditions under which it will burn all at once explosively; or on the surface with a flame.

Common coal gas of about the 14-candle power quality has about the following average composition.—(Lewes).

Hydrogen	52·16
Light-yielding hydro-carbons	3·50
Methane	36·25
Carbon monoxide	3·68
Carbon dioxide	0·00
Nitrogen	4·10
Oxygen	0·31
	100·00

Gas of this composition requires about five times its own volume of air for its complete combustion to carbonic acid gas and water vapour.

Now, assuming that instead of mixing it with any air, we discharge this gas vertically into the air under a constant pressure of five-tenths of an inch of water column, and light it. The burner shall be a "rat-tail," or simple jet. In still air this flame will extend to such a length as shall suffice to bring every particle of the combustible components into contact with the atmospheric oxygen, and so burn them completely. The flame itself only exists on the outside of the jet, and the cross-section of the jet being inconsiderable it is only lengthwise that the gas can expand. Consequently, assuming the diameter of the hole, the gauge pressure, and the atmospheric density as indicated by the height of the mercury of the barometer to be constant, the length of the flame will be a measure of the richness of the gas in combustibles.

This is so, and the instrument known as the "jet photometer," used in gas works to sample the quality of the gas as made, embodies this principle.

If, however, the gas should be too rich or the quantity passed too great, the top of the flame will smoke, thus indicating that the cooling down of the flame temperature by exposure has gone too far for the combustibles to burn at such a distance.

For this reason, in practice it is impossible to consume more than a small quantity of gas, of little use as a light, in the form of a jet. Verv early in gas engineering development, however, it was discovered that by causing two jets to impinge upon each other at a right angle, the gas flame would be spread out in a "fish-tail" shape; thereby exposing a large, thin upright sheet of gas to the air; which enabled a much greater quantity of gas to be effectively burnt. Another means of achieving the same object is to discharge the gas through a slit, which was called the "batwing" burner, the flame being wider and more ragged in outline than the "fish-tail," which later came to be called from its construction the "union jet" burner. The term "batwing" also fell into disuse, as the old crude way of manufacturing the burner of iron was improved upon. Finally, the two patterns of flat-flame burners were made to produce the same shaped flame with the same gas at the same pressure. Still, the appearance of smoking at the low pressure proper for this type of burner—5-tenths for 14 to 16 candle coal gas—remains the indication of the limit of good combustion; which for gas of this average quality will not exceed 10 cubic feet per hour for any single burner. An excess of pressure only causes the flame to "spur" at the edges and to roar, without yielding any more light.

Hence the consuming capacity of any luminous flame burner is limited; and the richer the gas the smaller the flame that can be completely burnt without smoking. Since ordinary main pressures are now greatly in excess of the low pressure suitable for a flat-flame burner, the correction may be cheaply made by combining a so-called "regulator" union-jet with an "economiser" tip, which slips over it, the difference between the numbers marked upon the bodies being proportioned to the excess of pressure to be dealt with. Thus a No. 1 "regulator" burner with a No. 5 "economiser" will ensure a good shaped flame with a common gas supply at 45-tenths pressure; because the excess of gas forced through the small burner according to the rule (Table I.), just adequately fills the larger tip.

Although the flat-flame burner is now obsolete as a means of producing the best illuminating effect from gas, it remains the safety light of civilization, and therefore its proper handling is of considerable importance. It cannot be dispensed with for exits from places of public entertainment, railway stations, in tunnels, stable yards, dormitory corridors and staircases, etc., where the object is not brilliancy of illumination, but the "showing of a light." Therefore, it is worth setting to work in a proper manner.

(The best flat-flame fitting for a danger spot is the "Breeden" pilot; which obviates touching the burner cock.)

TABLE IV.

Showing the consumption of 14 candle gas by Bray's "Regulator" union jet burners, Nos. 0 to 4, with "Economiser" slit union tips, Nos. 5 and 7; at 20-tenths pressure.

$\frac{5}{0}$	consumes	4·13	cubic feet	per hour.
$\frac{5}{1}$	"	4·58	"	"
$\frac{5}{2}$	"	5·55	"	"
$\frac{7}{3}$	"	7·17	"	"
$\frac{7}{4}$	"	7·82	"	"

For every 10-tenths additional pressure, use one number lower "Regulator."

Of the Quality of Town Gas.

MENTION has been made of the "quality" of gas in terms of its candle-power; and it is necessary to explain the meaning and significance of this term.

During the prolonged period of 75 or 80 years from the introduction of illuminating gas for the public and private lighting of towns, the standard of quality of the supply was, naturally, its illuminating power.

This was determined by comparison of the luminosity of a gas flame, by a standardised burner under standardised conditions of burning—as to rate of combustion per hour at a certain pressure—against the light of a specified number of standard candles.

The comparison was made by placing the gas light and the standard of light opposite one another, with a piece of white paper, a part of which had been treated with grease so as to render it semi-transparent, between.

The paper was carried upon a traveller running on a graduated rod, and therefore capable of being moved to and fro between the lights, until equality of lighting on each side of the paper was arrived at, as indicated by its uniform whiteness.

Then the distance of the paper from the two lights was observed, and the comparative brightness of the light calculated from the formula $I \backsim D^2$; that is, the intensity of the light emanating from a source regarded as a point in space, varies inversely as the square of the distance.

Thus, if the distance of the gas flame burning five cubic feet per hour from the paper is 80 inches, and of the candle 20 inches, the relative intensity of the two lights in $80^2 = 6{,}400$ and $20^2 = 400$; which is as 16 to 1. Therefore the illuminating power or quality of the gas is said to be sixteen candles.

So long as the luminous intensity of the gas remained its standard of quality, there was a rational presumption in favour of a high illuminating power. This rating ranged from 30 candle power (for the five cubic foot per hour standard burner) in parts of Scotland, where cannel coal was the natural raw material of gas manufacture, to 20-18 candle power in the Midlands of England, 16 candle power in London, and 14 candle power wherever else the seaborne coal of Northumberland and Durham was the recognised staple of manufacture. For many years there was a persistent struggle between the official representatives of the consumers, who believed it to be their duty to screw up the statutory illuminating power, and the gas companies who knew that this would involve the use of more costly grades of coal, for a very doubtful advantage.

The contest continued, however, until within the last few years, when the rapid increase of the consumption of gas for fuel purposes, in which illuminating power plays a much smaller part in regard to value for money; and the universal adoption of the incandescent mantle principle of lighting, in which it is of no importance at all, have combined to dethrone the illuminating power standard of quality of town gas.

How far the standard in question was from corresponding with the public use, even of luminous flame burners, will appear from the fact that the statutory quality, with the rarest exceptions, was never realized by the ordinary consumer. While the costly Scotch cannel gas was nominally rated as of 30 candle-power, in point of fact no consumer of such gas used burners of the capacity of five cubic feet per hour, which could alone have developed this degree of luminosity. The usual burners were small and bad, so that while the gas was supposed to be the brightest in the world, the towns where it was distributed were the worst lit on earth. In London, as late as 1900, when the first proposition was made for a reduction of the statutory candle power of the gas from 16 to 14 candles, it was ascertained that the majority of the public were using bad flat flame burners only capable of giving 6 or 8 candle power for the same consumption of five cubic feet per hour.

The Development of the Luminous Efficiency of Gas.

It was discovered by Sir Humphrey Davy that the source of the luminosity of flames is the burning, in contact with air, of solid particles of carbon liberated by the heat from the more or less unstable compounds of carbon and hydrogen composing the combustible matter. Vivian B. Lewes has carried the investigation farther (see his book on "Liquid and Gaseous Fuels," in Constable's Westminster Series, 1907, page 173 onward). The explanation agrees with the appearance of any hydro-carbon flame, in which the bottom portion of the flame is blue and transparent, and the upper luminous portion is yellowish-white and opaque. The statement of Lewes is that "the small blue portion of the outer envelope at the base of the flame is caused by the rapid inrush of air, the nitrogen so diluting the hydro-carbon molecules at that point that they are burnt up without being first decomposed, and there being therefore no separation of carbon, there is no luminosity." Higher up, the heat decomposes the carbon compounds and the solid particles burn with bright incandescence. If this combustion of the solid carbon is interfered with, by wind or the intrusion of some foreign body, the unburnt carbon becomes visible as smoke or soot.

Thus, not only is the luminosity of a hydro-carbon flame due to the incandescence of solid carbon particles; but the higher the temperature at which the incandescence occurs the brighter will be the flame. Where the carbon density is greatest. the luminosity will be brightest; because the crowded incandescing particles help to heat one another. (In this way Lewes explains the high luminosity of the acetylene flame.)

It follows also from the foregoing that the hotter any gas flame can be kept the more luminous it will become. Carbon itself burns readily at a comparatively low temperature; and therefore under such conditions as prevail, say, in a coke fire, not much light is produced. Yet it is identically the same substance burning in a coke fire and in the acetylene flame. The different effect in point of luminosity is due to the difference of the effective temperatures.

It is not possible to make common coal gas burn freely in air so as to yield a greater luminous duty than about 3 candle power per cubic foot of hourly consumption; and this is only obtained with a carefully proportioned Argand burner having a correctly adjusted air supply. Such a burner is the Metropolitan Argand Burner No. 2.

The best flat-flames, being over-exposed to the air, will show 10 to 20 per cent. less light from gas of the same quality and rate of consumption.

About 30 years ago, Friederich Siemens, of Dresden, succeeded in raising the effective temperature of combustion of a low-carbon town gas by superheating the flame with heat recovered from its own combustion products. His lamp, which was the forerunner of several varieties of the type, was based upon the principle of "a closed system of heat exchanges." The hot products of combustion were led away from the flame in flues which were surrounded by the channels conducting the fresh air to the flame, the efficiency of which was thereby increased to almost 9 candle power per cubic foot of gas consumed. Lamps of this type had to be on rather a large scale to derive the full benefit of super-heating.

In 1885 a new chapter in gas lighting was opened by the discovery by Dr. Auer von Welsbach of the superior luminous incandescent efficiency of the oxides of certain "rare earths" when heated in the bunsen, or non-luminous gas flame. In course of time it was ascertained that the most efficient preparation for the purpose is a mixture of thorium oxide 99 per cent., and cerium oxide 1 per cent.

Suitable textile fabrics, such as cotton or ramie fibre, artificial silk, etc., are impregnated with a solution of the nitrates of the two metals, in the stated proportions. The fabrics are then either dried and laid by for placing upon the burners in the "stocking form," to be burnt into their working shape *in situ;* or they are shaped upon moulds and the fabric burnt off. This converts the nitrates into oxides, which remain as extremely fragile skeletons of the original fabric. The next stage is the tempering of the mantle in a high-pressure blow-pipe flame, which produces incipient fusion and thereby imparts sufficient strength to the skeleton to permit of its being handled with care, and carried about suspended in glass tubes for local "mantle maintenance." Otherwise the tempered mantles are dipped in a preparation of collodion, and when this has dried off are boxed for transport.

Uncollodionized mantles are preferred where it is possible to procure them, because the collodion in burning off is apt to strain and break the fragile skeleton, thus shortening the life of the mantle.

The explanation of the superior luminosity of the mantle, as compared with that of the carbon particles of any hydro-carbon gas flame of less density than acetylene is now referred to a temperature effect pure and simple. The skeleton of the oxides is highly refractory, unlike carbon, which, as already observed, begins to burn away at a low red heat. It therefore stands the highest temperature of the bunsen gas flame, at which the incandescence becomes very vivid. On the face of this fact, no further explanation would seem to be necessary, inasmuch as a temperature of 1,750° Centigrade has been measured on the outer edge of a well-aerated bunsen flame, where the mantle should fit; and a temperature considerably lower than this, namely, 1,500° Cent. is listed by Pouillet as "dazzling white." This it may well be, seeing that the temperature of molten steel is about 1,400° Cent.

Various other explanations of the brilliancy of the mantle have, however, been offered; and scientific opinion is, or has been, divided as to which is the hotter—the mantle or the flame. The cause of this scientific curiosity is the remarkable fact that whereas the thorium oxide, which is the more costly material, gives the skeleton mantle its strength, this substance alone possesses hardly any power of emitting light. It is only the almost infinitesimal proportion of cerium oxide to which the luminosity of the mantle is due; and neither more nor less of this component is of any use in this respect. For all practical purposes, however, it may be concluded that the luminosity of the mantle is an effect of the temperature of the flame. This conclusion is upheld by the fact of intensification of the luminosity by super-heating, or by high pressure combustion. All mantles are of the same ultimate composition, and the intensity of their light depends upon the after treatment to which they are subjected.

It must be remembered that the invention of Dr. von Welsbach was confined to the mantle. Having first discovered the remarkable properties of refractoriness, strength, and light emissivity in the "rare earths," which had previously been regarded as mineral curiosities without commercial value, Dr. von Welsbach proceeded to devise the practical means of developing these qualities in the heat of the bunsen gas flame—namely, by the mantle. This marvellous invention remains essentially as it sprang from Dr. von Welsbach's brain; although, of course, its preparation and sale have become standardized and commercialized. The once "rare" raw materials of its manufacture have been found in abundance in various parts of the world; and there is no probability of their running out or being "cornered."

The consequences of this invention to the gas industry and to the civilized world at large which uses fixed artificial lights, have been enormously important. The efficiency of gas as an illuminant has been increased ten, twenty, and even thirty-fold; and the end is not yet in view. If the employment of pure oxygen to burn the gas became feasible commercially, as it is practically, the illuminating value of gas would be doubled upon the foregoing figures.

Actually, meanwhile, the Welsbach light has created a new standard of artificial illumination in town life; and it has incidentally revolutionized the gas industry.

Coming as it did at the same period as the general adoption of gas for domestic cooking and the dawn of its use for heating purposes generally, this alteration of the principle of gas lighting—from the use of the luminous flame to that of a system based upon heating effect—turned the course of the industry of gas manufacture. Instead of a high illuminating power of the luminous flame, the requirement of a town gas supply was changed to that of a cheap gaseous fuel. Heating power, not simple flame luminosity, became the real criterion of its value for money. If it had happened that a high illuminating power, measured by the old method, was identical with a strong fuel test, the ancient standard of quality of town's gas would have received a renewed lease of life. Fortunately for all the interests concerned the opposite proved to be true of the new situation.

For the first time the heating power of town gas then received attention, and was brought under exact measurement. The manner of this is explained in another chapter. Meanwhile, the main point in regulating the new industrial situation created by the predominance of the Welsbach light is the fact that *calorific power* (which is the measured heating capacity of town gas) is not the sole measure of its efficiency in light production by the agency of the Welsbach mantle. *Flame temperature* is also a factor in this particular heat effect. It does not follow that the most powerful fuel burns with the hottest flame. So with town gas, a comparatively low calorific power gas by calculation or actual determination with the calorimeter, by reason of the correspondingly small volume of air required for its combustion may have as high a flame temperature as a gas of higher calorific power and larger air requirement. And since the former sample will be cheaper to manufacture than the latter it will serve the public better all round.

The Welsbach Light and Mantle Maintenance.

It has been stated that the Welsbach invention was limited to the mantle. It did not include the burner nor any of its accessories. It is not necessary to catalogue or discuss the various types and descriptions of mantles in the market. The master patent for the preparation of the "dip" has long expired; and the numerous subsidiary patents for particular details of mantle design and construction have only a trade value. Tests for all goods of the kind are their brilliancy and endurance. It is not true, as sometimes asserted, that falling off of luminosity in use is a characteristic of all mantles. The chief item of cost in mantle manufacture is the impregnating solution, and therefore the value of a mantle largely depends upon the degree of thoroughness of its impregnation. Mantles lightly dipped will glow brightly enough for a time; but quickly perish. A working test is the best guide, because the vicissitudes of particular localities greatly differ. Public street lamps offer the severest test for the durability of mantles. Tramway routes and market roads are more trying than quiet side-streets. For this reason it is difficult to state an average term for the life of mantles. In private lighting with care they may last a very long time, and not show any noticeable falling off of luminosity.

The popularity of the Welsbach light was greatly assisted by the introduction of "maintenance" by the gas undertakings. Naturally, a public so incurably heedless of its proper interest in the choice of efficient flat flame burners (see *ante* p. 78) was not to be expected to turn over a new leaf immediately a fresh system of gas lighting was introduced; and for some years it remained doubtful whether the new light with all its advantage would "catch on." The offer of mantle maintenance prevailed to turn the scale. Originally this system meant that for a fixed charge of so much per burner, usually 8d. or 9d. per quarter, the whole care of the lighting would be undertaken and visits paid at short intervals, or as required, to renew mantles, chimneys, clean the burners and see that the light was satisfactory.

In the organisation of a working department for this service certain disciplinary and economical measures are expedient, and can be ascertained by inquiry of undertakings practising the system. In many, perhaps the majority of cases, the original plan of a fixed charge has been superseded by that of charging for materials alone, the labour being given gratis. It is often found also that after a little experience the consumers are able to look after their own lamps. This is desirable in the case of prepayment consumers.

Incandescent Gas Burners: The Upright Burner.

THE incandescent lighting burner, as compared with the flat flame or other luminous gas burner, is a high-pressure apparatus; because it is a bunsen, which requires an average pressure at the nipple of 20-tenths to draw into the mixing tube the proper proportion of "primary" air.

Although upright incandescent burners will work fairly well at a pressure as low as 16-tenths or as high as 25-tenths, a uniform pressure of about 20-tenths at the nipple gives the best results with gas of the 14-candle quality.

In the absence of governors, regulators or adjusters for the gas and primary air are a great improvement on the use of the burner cock for the purpose. The adjustment should be independent of the cock; which should be turned on full while the gas is alight. The object of the adjustment is to allow sufficient gas to pass to completely fill the mantle, and sufficient primary air to completely burn the gas (with the aid of the "secondary" air) at the surface of the mantle. Burners with chimneys, of the Welsbach type, usually draw up their flame a little when the chimney becomes hot.

The Welsbach "C" Burner, which became the standard size, is an excellent burner for all suitable purposes. It should show, with a good, sound, well-fitting mantle, truly vertical and steady, clean chimney and burner top and nipples free from dust, a luminous efficiency of not less than 18 candle power per cubic foot of hourly consumption, with 14-candle gas. Thus, for an average consumption of 3½ cubic feet per hour, the light obtained will be of about 63 candles' intensity, measured horizontally at the middle height of the mantle.

This efficiency is surpassed by some other styles of upright mantle burners; but the Welsbach and the Bray patterns are very convenient for keeping in good order, as the upper part can be lifted off the burner tube and replaced with a fresh chimney and mantle complete. The Welsbach is improved by the substitution of a "normal" chimney, with air holes, for the straight chimney; care being taken to close the bottom of the burner at the same time with the brass cone provided for the purpose. The Bray burner bears turning down better than most.

The Kern burner is a decided improvement on the Welsbach in regard to lighting efficiency, which may be 20 per cent. higher. This is due to the larger proportion of primary air drawn in by the Kern "venturi" shaped burner tube for the same gas pressure; and also to the better mixture of the air and gas in the head of the burner. The result, according to the inventor, is to produce a bunsen flame with a "zone of hyper-incandescence" forming the outer sheath of the flame where the mantle is. This burner does not require a long chimney; but is all the better for a short one to protect the mantle from draughts. Its chief defect, according to some users, is the tendency of the flame to cut the mantle at the level of the burner top. The Kern burner was introduced in graduated sizes, numbered from 1 upwards, the numbers representing the gas consumption in cubic feet per hour at 10-tenths pressure; but the smaller sizes did not become popular in the English market, which preferred more light to the extreme economy of gas thus rendered possible. The No. 4 Kern has been largely employed for public street lighting.

The Kern burner was made "self-intensifying" by fitting a long chimney to the larger sizes. The effect of this increased chimney draught was to pull in more primary air, without throwing this additional mechanical work upon the gas. This was equivalent in effect to increasing the gas or air pressure. Thereby the same burner and mantle are enabled to consume twice the quantity of gas, and produce rather more than double the light. That is, a No. 6 self-intensified Welsbach-Kern lamp will burn up to 12 cubic feet of gas per hour, the same as if the gas pressure were quadrupled (see Table I.), and the amount of light will be in rather higher proportion, owing to the increased temperature attained by the mantle in the more energetic flame.

This is also the explanation of all intensification of luminosity by the agency of high pressure, either of the air or the gas. Every high-pressure lighting system operates by concentrating more air and gas, and consequently more heat within a given size of mantle. The pressure in all cases is expended on increase of velocity of the mixed air and gas in the burner tube. Either the gas or the air may be employed under increased pressure in this way; but not both together. The mantle would not bear any actual increase of pressure within itself; but this can never happen while one end of the bunsen tube is open to the atmosphere.

"Intensification" of the light of the incandescent mantle is accomplished by three methods, which may be realized singly or together.

Illuminosity of a mantle may be simply increased, that is to say, by (a) forcing or drawing more air and gas into a mantle of a certain size than is practicable with ordinary main gas pressures and a natural air supply. The means adopted in various systems for effecting this increase of consumption are simple gas pressure-raising apparatus, such as Keith's water-power appliance, which works up to nine inches gas pressure; or Sugg's gas engine or hot-air engine arrangement, increasing the gas pressure to 17 inches. A self-intensifying lamp having a powerful chimney draught, as already remarked, will have a similar effect. Air pressure systems also belong to this first category; the distinguishing characteristic of which is that the intensification is chiefly *quantitative*—that is, the enhanced brilliancy of the light is more a matter of larger consumption of gas within a mantle of a certain size, than of a positive increase of the luminosity per cubic foot of the gas itself.

Another method (b) relies upon the increase of the temperature of the bunsen flame by super-aeration. This is the method employed in the Sale-Onslow, Millennium, Keith's and other high-pressure systems, in which pressures of four inches of mercury and upwards are utilized to increase the primary aeration up to the limit of the total air requirement of the gas, leaving little or nothing to the secondary aeration of the flame. The use of the higher gas pressure is to impart such a high velocity to the flow of the gas and air mixture (which is explosive) in the bunsen tube, that it shall exceed the rate of backward propagation of the explosion flame. Consequently the flame remains steadily at the end of the burner tube, without lighting back. As is explained in the chapter relating to the bunsen burner (p. 130), the higher the primary aeration of the bunsen flame up to the limit of maximum explosive effect, the smaller and hotter it becomes. Therefore, by setting the mantle in such a flame, its luminosity is truly intensified *qualitatively* as well as *quantitatively*.

This effect may be produced otherwise, as by mechanically driving in the necessary proportion of primary air at sufficient velocity by means of a fan or pump. Examples of this are the Lucas thermopile-driven lamps, and the mercury-vapour pump lamp.

One system, the "Selas," first mixes the gas and the air in the proportions of 1 of gas to 1½ of air, under pressure, before the final bunsenizing at the burner; for which much advantage is claimed.

The third method (c) of intensification depends upon superheating of the mantle by heat recuperation; which is independent of increase of air or gas pressure. For this an "inverted" form of incandescent lamp is essential.

The Inverted Burner.

THE invention of the inverted incandescent gas lamp dates from the beginning of the present century. It involves far more than merely turning a Welsbach "C" burner—the only kind of incandescent gas burner known at the period—upside down.

If the Welsbach burner is examined it will be noticed that the injector nipple is pierced with five holes, the reason for which is that the current of gas shall mingle with and spend its moving energy as quickly as possible upon the air to be drawn in and forced upwards as "primary" for the bunsen flame. The mixing tube is short, terminating in an enlarged head, in which the velocity of the bunsen mixture finally disappears; so that a chimney is necessary to draw in the "secondary" air and stiffen the flame. The mantle is long and closely fits the burner-head.

If such a burner were turned upside down and the gas ignited, the flame would merely turn back and burn up round the head of the burner, so that it could not possibly incandesce a mantle. Evidently, therefore, what is wanted is for the inverted flame to stand out sufficiently beyond the bottom of the tube to have a mantle fitted to it.

This means concentrating the stream of gas and air in the downward direction; which is effected by making the bunsen tube of small bore, and injecting the gas in a single jet. The gas injector, the bore, and the length of the bunsen tube must bear a correct proportion to one another, and also to the gas pressure, in order to produce the required result of a bunsen flame standing outward and downward from the bottom end of the inverted bunsen tube. The mantle (in low pressure burners) also hangs off from the end of the tube to reduce resistance and to allow the secondary air to have access to both sides.

Next, the primary air inlets must be protected from the rising products of combustion. This is done by interposing a baffle between the air holes and the downward prolongation of the bunsen tube, so that the ascending combustion products shall be thrown off from the neighbourhood of air inlets. Usually also the products are deflected from an upward direction by a shell-like cover, with a view to scattering and thus preventing them from ascending directly to the ceiling.

If the combustion products were permitted to enter the primary air holes the flame would be rendered unsteady.

An inverted gas lamp for interior use should either have the gas pressure governed to 25-tenths, or be fitted with a regulator or adjuster for the gas and the primary air. It also requires a suitable globe. In regulating the light, the gas and primary air must be adjusted so that the flame just fills the mantle. Too much gas is as bad as not enough. The character of the bunsen flame should be fairly "keen"—i.e., showing a distinct green inner cone, without hissing—10 minutes after lighting up.

An ordinary inverted lamp alters the character of its flame, as the result of the bunsen tube getting hot. Heat produces a "chimney effect" in the tube itself, which is merely a pipe open to the air at top and bottom, with a hot fire at its lower end. It is only the pressure of the gas which causes the flame to burn outwardly. As the tube gets hot, however, the descending primary air also becomes heated by contact with the inside of the tube; and thereby acquires the tendency to form an ascending current. This is the "chimney effect." It offers resistance to the downward flow; and this resistance affects the flow of air, which is only an induced current, more than that of the gas, which is a positive discharge under pressure.

In the cheaper makes of small inverted lamps, with metal tubes unprotected from the heat of the flame, it is usually necessary to adjust the air admission so as to start cold with an excess of primary air. The noise will cease as the tube gets hot, and the balance of the air and gas currents becomes established. The usual luminous efficiency of simple inverted lamps is about 22 candle-power per cubic foot of 14 candle gas.

The inverted form of gas lamp, for the same reason, readily lends itself to the process of intensification by heat recovery. Beginning with the protection of the flame and mantle by means of an inner hard-glass jacket, the process is carried to its fullest capability in the high-power low pressure intensified lamps with multiple mantles. The mantles for such lamps should be carried upon " skeleton " rings.

Here the principle of a balance of heat exchanges in a closed circuit is carried into effect, with the result of raising the luminous efficiency of the gas and the mantle to about 40 candle-power per cubic foot. Practically the whole of the air drawn in is super-heated by heat abstracted from the waste products of combustion. This operation is necessarily gradual; because, starting cold, the lamp has a considerable weight of material to heat up, which usually takes 45 minutes. During this period the intake of air is being accelerated. Therefore, when lighting-up " Nico" lamps of this class it is necessary to start with a "slack" bunsen flame—not showing any green inner cone. Eventually the primary aeration will be increased to the correct degree. If such a lamp is started with an apparently correctly aerated flame, it may become over-intensified and perhaps melt the inner glasses.

The degree in which it is necessary to observe this precaution is not the same with all patterns of such lamps. The point, therefore, requires attention in every case.

In the high-pressure inverted Keith lamp, all three methods of intensification are operative—increased gas consumption for the size of mantle, increased primary aeration of the flame, and super-heating of the combustible mixture. The result is the highest luminous efficiency of the gas hitherto attained, namely, 60 candle power per cubic foot of hourly consumption. The bunsen mixture actually burnt when the lamp is in full gait, which is arrived at in 30 minutes from lighting-up, is that known to produce the most violent explosion when ignited in the ordinary way. This proportionate mixture is formed gradually, as it would be impossible to light such a mixture at first hand without explosion. Starting cold, therefore, the primary air supply is not more than will burn with the gas quietly at the end of the tube—say, 2·5 parts of air to 1·0 of gas. As the body of the lamp heats up a thermoscope uncovers another air inlet, and the correct mixture is gradually formed, while the high rate of flow due to the pressure prevents back-firing.

The increase of pressure is most conveniently effected by means of a rotary blower; actuated on the spot by a gas engine or electro motor in the absence of a general high-pressure supply (Fig. 20).

The power required for raising the gas pressure is given by the formula :—

$$\text{H.P.} = 0{\cdot}005\, h\, v.$$

Where H.P. = brake horse-power.
h = gauge pressure, inches of water.
v = thousands of cubic feet per hour.

The total expense of the gas power required, including all running costs, depreciation, etc., is usually reckoned at a penny per 1,000 cubic feet per hour.

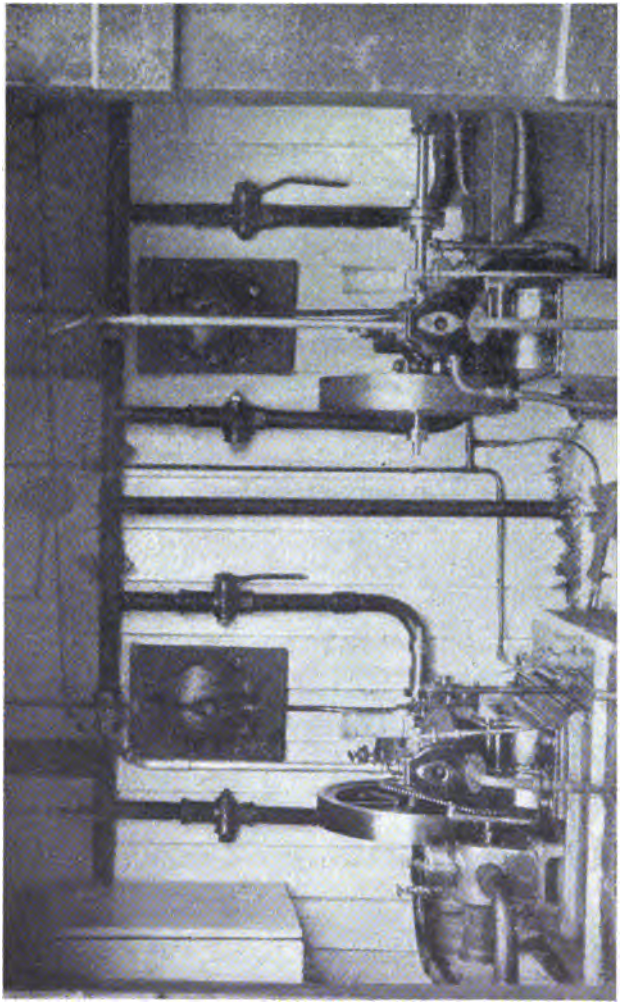


Fig. 20. SMALL GAS-COMPRESSING PLANT, IN DUPLICATE.
Shed Dimensions—height, 4ft. 10in.; depth, 4ft.; width, 8ft.

There would be a rise of temperature due to compression of about 6° Fahr. for every lb. per square inch, or two inches of mercury gauge pressure increase.

The gas supply for a small district high-pressure installation may have to be taken from a comparatively small main, in which case there would be risk of causing oscillation of pressure in the vicinity. This can be obviated by interposing in the engine service connection a length of 8in. or 9in. cast iron main pipe to act as a reserve and cushion for the intermittent flow of gas.

Lighting by Incandescent Gas Lamps with special respect to Shades.

THE science and art of lighting are concerned with the correct and pleasing application of artificial lights to their intended purposes.

Artificial lights and lamps of all sorts are, as a rule, required for the purpose of serviceable illumination rather than as ornaments in themselves, although the two objects are often combined.

The " illuminating power " of a gas lamp is usually understood as meaning the luminous intensity, measured by a photometer against a standard of light and expressed in terms of British standard candles, of the horizontal ray of its light, without reflection or shading. The symbol of this quantity is written I.

Such luminous intensity, regarded as proceeding from a point in space (in practice, in a room with dead black walls, ceiling and floor), is assumed to be subject to the general law of diffusion of radiant energy in all directions, according to which the intensity measured at a distance from the point source is

$$\frac{I}{D^2}$$

In words, " The luminous intensity of a point source radiating equally in all directions varies inversely as the square of the distance."

If D is measured in feet, and I in standard candles, then dividing I by D squared, gives the illumination at the distance D in *foot-candles*.

EXAMPLE:—If a gas lamp has a luminous intensity of 100 candles, at a distance of 10 feet the lighting received will be of the order of 1 foot-candle, because

$$I = 100\text{c.};\ D = 10\text{ ft.}\quad \text{Therefore}$$
$$\frac{I}{D^2} = \frac{100}{10^2} = 1 \text{ foot candle.}$$

It corresponds in effect to the amount of lighting received from one candle at a distance of one foot.

The reason for this rapid falling off of radiant effect with distance is a matter of geometrical relations, and is usually explained by a figure like the following: (Fig. 21).

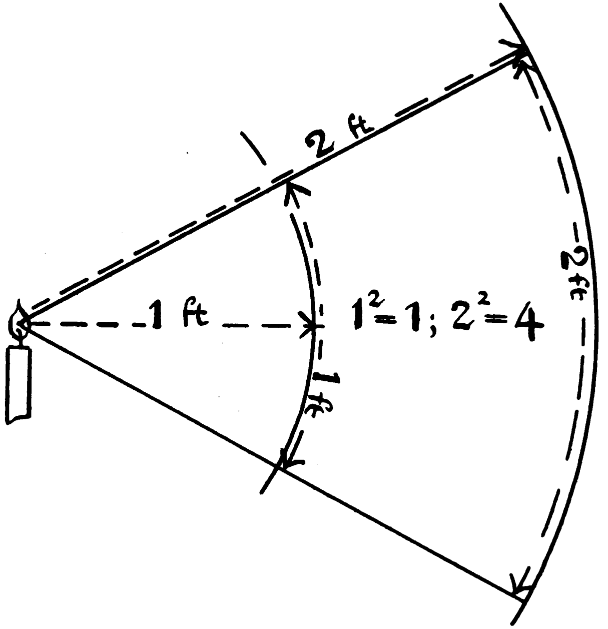


Fig. 21. DIAGRAM ILLUSTRATING GEOMETRICAL DIFFUSION OF RADIANT ENERGY.

It will be perceived that it is merely the spreading of the ray, radiating from a point in space, over the larger superficies that accounts for its diminution of intensity. All the energy is there, just the same, so long as it is not actually absorbed by something in the air, such as smoke or mist.

Therefore, if such a ray, which so soon spreads out into a bundle of diverging rays, is collected by a lens of the " bull's-eye " form into a parallel beam, it will not suffer any further diminution other than by atmospheric absorption.

Again, if such a lens is backed up by a suitable reflector on the opposite side, catching as much as possible of the light otherwise going away divergently in this direction, the beam will be reinforced by so much more light.

This arrangement represents what is called a " search light " beam, which is not subject to the law of diminution according to distance, except by absorption and a certain degree of spreading which cannot be avoided.

In yet another regard the aforesaid law is inoperative; and this is when the source of the light is not a point, but is a larger superficies. This is, indeed, the reversal of the effect shown by the figure (Fig. 21). It is the geometrical effect the other way about. If the superficies at 1 foot distance is radiating light of a certain intensity, the removal of a receiving point to *twice* the distance will merely expose it to the receipt of the radiation from *four times* the area, and therefore of equal intensity.

These two styles of artificial light which do not come within the operation of the law of inverse squares must be kept in mind, especially as warnings of the effects of reflectors and lenses on the distribution of different kinds of artificial light. When any lighting is done by a collected beam, or from a large superficies raised to a useful luminous power of surface brightness, the photometric method of comparative measurement ceases to apply.

The "foot-candle" is an expression which is a calculated figure, and although perfectly intelligible and competent to indicate degrees of the actual lighting of illuminated objects, is not directly measurable by an instrument of the photometer type.

It can be arrived at by observation, however, by the aid of special instruments based upon a balancing of the apparent brightness of illuminated surfaces in juxtaposition.

A handy instrument of the class is the "Lumeter," in which a comparison can be made of the illumination actually falling upon a dead white standard surface from a standardized lamp; and also from the outside illuminant. Or, the surface brightness of a visible object can be measured, both in terms of foot-candles.

Surface brightness = actual illumination received *minus* proportion not reflected.

TABLE V.

Table of the Reflecting Power of Surfaces, in per cent. of the incident light.

White paper, clean whitewash ...	82
Printed page, good paper	75
Newpapers, average good	70
Light tinted wall paper	65
Medium " "	55
Yellow ground "	50
Blue " "	25
Emerald green "	18
Dark " "	12
Dark brown "	10
Dead black paint.	0·1

The foregoing figures explain the cheerful aspect of light-coloured, bright and clean frontages of buildings, ceilings, wall-papers, well whitened factories and workshops, etc., as compared with the gloominess of dingy and dark surfaces. The latter, however, are sometimes deliberately chosen for restful effect, and as a vanishing background for pictures and statuary.

Although it is easy and trustworthy to calculate the amount of light actually given in a room from the luminous intensity and position of the lamps, where there is much cross-lighting and the reflective power of the surroundings is doubtful, it is advantageous to check the results achieved by Lumeter observations; especially where there is any question of comparison of different systems.

The average of good lighting for interiors, with modern gas lamps, is about as follows:—

TABLE VI.

	Foot Candles.
Lowest on floor of living rooms, public lecture halls, counting houses, etc....	0·5
Lighting of desks, counters, dining tables	2·0
Comfortable reading light for smallest print of newspapers	2·5
Drawing boards, etc. (lighted from left front)	3·5
Watchmaker's benches, etc.	5·0
Show stands in shops*...	10 to 40·0

(* This last is an advertisement standard only; being far in excess of any requirement for visibility.)

There is, of course, an enormous proportion of gas lighting for domestic purposes, drawing rooms, bedrooms and offices, for which no precise measurement of illuminating effect can be laid down. Common sense and good taste will always have the last word in these matters. The golden rule will be found in adapting the amount of illumination to the purpose and the situation, avoiding extremes.

Still, there are a few sound guiding rules, which, even if allowing for much exception, will conduce to good results. These may be epitomized as follows:—

Avoid glare. A glaring light is a light that is in a wrong place; or that shines too brightly into the eyes. This defect can usually be avoided by keeping the lamp well up above the line of sight; or by interposing a translucent screen of opal, ground, etched, prismatic or tinted glass or fabric between the light itself and the eye; or by backing the mantle with a matt white surface of comparatively large area.

Allow from 30 to 50 candle power of light to every 1,000 cubic feet capacity of interiors, according to the scale of illumination preferred.

Proportion the power of the light source to its distance from the spectator or user. Small rooms call for small lamps; the larger the apartment the more powerful may be the lamps used for lighting it. This is irrespective of the actual amount of lighting at, say, the floor level. Small and large interiors may have the same average illumination; but provided in different ways. This is where the *art* of illumination comes in, as distinct from the *science*.

Domestic lights of the ordinary class should in general be fixed at a clear height of 6ft. 6in. above the floor. Wall brackets should be stiff and short. In drawing rooms multiplication of lights, well shaded with silk or beads, gives the most pleasing effect. The same rule also applies to the wall lighting of panelled or very darkly papered or tapestried dining rooms, etc. "Bijou" inverted, or if preferred candle-form small upright units may be employed. Over dining tables the light must be concentrated, and the lamps screened from the eyes of people sitting at table by deeply fringed almost opaque shades. These pendants may be adjustable for height; but this is not really necessary.

There is a totally different style of lighting, very appropriate for many interiors, domestic and others, known by the classifications "indirect" and "semi-indirect." In the former the source of the light is entirely invisible, and the illumination proceeds from the ceiling or frieze, either by indirect reflection or by transmission from without through a translucent medium. In the latter the lamps are present in the room; but are screened from direct vision by translucent shades which reflect the light first to the ceiling.

Either arrangement can be very successfully adapted to large or small interiors. The House of Commons was indirectly lighted by gas in argand burners above a false ceiling of stained and ground glass, by the late Mr. William Sugg. The plan has been copied for numerous municipal council chambers, concert and assembly rooms, etc.; and is specially suitable for public halls likely to be occupied by day as well as in the evening, because the transition from one means of lighting to the other can be effected insensibly.

Church assembly halls, parish rooms, etc., converted to the purpose of a Fancy Fair, can be treated in this way by suspending decorated and fire-proofed muslin underneath extra lamps for the occasion. This combination of lighting and scene-painting attracted much attention at the Anglo-Japanese Exhibition in London. It is also a good way of lighting picture galleries and museums, because of the almost complete absence of shadows.

"Semi-indirect" lighting can be made very ornamental and agreeable to the style of decoration of the apartment. It consists in the employment of opal, ground glass, or other translucent reflector-shades underneath the lights. Thus it is a reversal of the ordinary disposition of lamps and shades. The system demands a clean white-washed or painted ceiling, and distance or pilot light ignition. In either of these systems of lighting the amount of light required to be provided is twice as much as would suffice for ordinary direct lighting; but gas light is so inexpensive that this consideration is less serious than it would be with any other illuminant. The difference in gas consumption between an ordinary inverted lamp used directly—*i.e.*, with a simple etched globe—and one with a clear glass globe over a semi-indirect reflector shade might represent an increase of luminous intensity of from 50 candle-power of 100 candle-power—merely the cost of four cubic feet of gas per hour instead of two cubic feet, per point.

Fig. 22 shows the principle applied with its own top reflector; for schools, shops, etc.

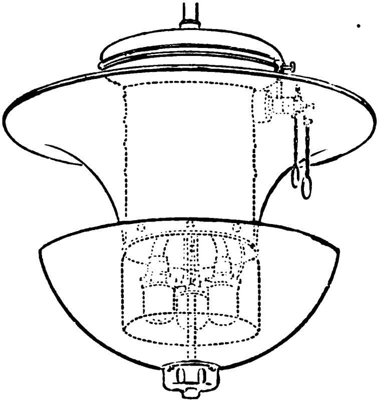


Fig. 22. Semi-Indirect Lighting Fixture.

As regards ordinary direct lighting, it should be a general understanding that no incandescent mantle light, great or small, upright or inverted, should ever be used without a shade or reflector appropriate to its position and purpose. A naked upright mantle is an offence to the eye; unless it is in a public street lamp with a top reflector, when it is never sufficiently near to the eye to cause annoyance.

The science of reflectors and shades is based upon the simple proposition that "the angle of reflection is equal and opposite to the angle of incidence."

This fact and its practical consequences in the distribution of the light of a gas lamp are illustrated by the figure, which shows the natural path of the rays, and the same as modified by reflection.

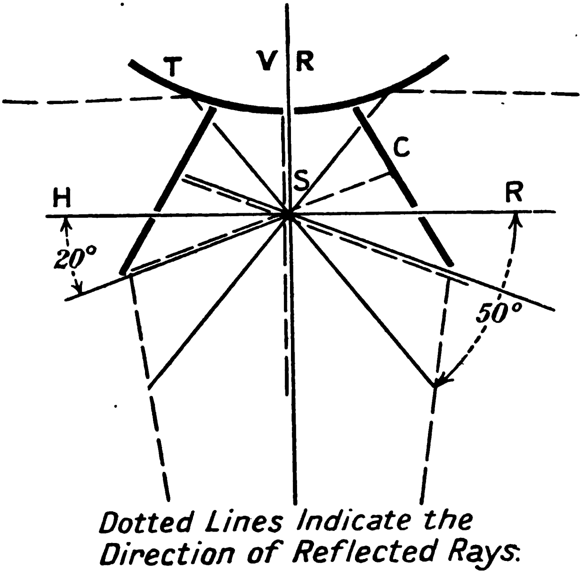


Fig. 23. DIAGRAM ILLUSTRATING THE DIRECT REFLECTION OF LIGHT.

S.—A Source of Light, regarded as a Point in space.

H.R.—The Horizontal Ray, the measured Intensity of which is usually taken as representing the "Illuminating Power of the Source," without reflection or focussing by any lens.

V.R.—The Vertical Ray; useful for direct lighting downward from an Inverted Gas Lamp. The upward ray is chiefly useful when reflected downwards as in "indirect" lighting.

T.—The Top Reflector of a Street Gas Lamp, the convexity of which is designed to scatter at various downward angles the direct upward rays of the Source.

C.—Any reflecting surface disposed at such an angle with the vertical as will intercept the direct rays above the horizontal, and reflect them downwards. This part of a Lamp Shade is ordinarily made of "opal" or etched glass. The "Holophane" system of shading embodies this principle very perfectly.

The rays between 20° and 50° below the horizontal are the most useful for Public Street Lighting, and the measured Intensity of a Source, without reflection or lens, at these two angles has therefore been specified in important contracts for this Service (see p. 126).

The advantage of reflector-shading is greater in the case of the upright than with the inverted mantle; for the following reason. In treating previously of the law of the diffusion of light from a point in space, it was mentioned how ordinarily the illuminating power of a lamp is taken to be that of the horizontal ray.

This assumes that all the rays of such a source of light are of equal intensity, so that it matters not which is taken for the purpose of measurement of luminous intensity, except for convenience. Since the comparison of the relative brightness of two common lights is most conveniently made horizontally, the horizontal ray is chosen accordingly.

In point of fact, while this assumption is partly justified in respect of incandescent mantles, of which the horizontal aspect is the most favourable, it is not correct as regards the equality of the radiation in other directions. The total light distribution of the upright mantle is greater for the upper range, above the horizontal line drawn through the centre of the mantle elevation, than for the lower directions. The excess in the upper directions is at least 20 per cent.—that is to say, 60 per cent. of the total light goes upwards and 40 per cent. downwards, from the middle horizontal line. In the case of the inverted mantle the reverse is the fact, only more so.

In general, except for the purpose of indirect reflection from the ceiling, the light of lamps of all kinds is required downwards and to be shadowless. The upright mantle therefore is imperfect in this respect, and its excessive upward radiation should be intercepted by a suitable reflector-shade and re-directed downwards.

Generally speaking, where opalized glass is used for shading—that is, interposed between the mantle and the eye to soften the direct rays at close quarters—it is unnecessary to have the whole globe obscured. It should be remembered that although this softening of the too intense brilliancy of the mantle is desirable for the sake of the eye, and so far from detracting from its visual power really assists perception by allowing the iris to expand—yet the actual intensity of the light of a mantle so shaded may be reduced by 30 or 40 per cent. Therefore, this remedy against "glare" should be resorted to with discretion.

Where powerful direct lighting is required at close quarters, as for an operating table, or a dentist's chair, it is advisable to use a good sized inverted lamp with a *large* ground glass globe. The surface intensity of such a mantle is in the neighbourhood of 40 to 50 candle-power per square inch of the visible superficies. This brilliancy, encountered by the eye at a short distance, would produce temporary blindness. Even if the light did not directly strike the retina, but merely entered the eyeball sideways or from above, it would tend to paralyse the vision. In the case in point, it would therefore be necessary to soften the direct light until it could not injure the operator's eyes, while illuminating the object of his attention to the utmost desirable degree of clarity. This result would be ensured by enlarging the apparent source of light, namely, the translucent globe, in such a measure as to bring its surface intensity down to a figure such that the eye could rest upon it momentarily, or be exposed to it sideways, without danger. Such a degree of safe brilliancy is that of a flat-flame gas light, which never exceeds three candle-power per square inch and is more commonly less.

Let the permissible surface brightness of the visible source of light in the present case be 2·5 candle power per square inch. The luminous intensity of the inverted lamp is 120 candle-power. Of this radiation a ground glass globe will stop 25 per cent., leaving 90 c.p. to pass. To soften this intensity to the required figure will need a shade of $\frac{90}{2{\cdot}5}=36$ square inches of visible plane superficies; which will be provided approximately by a 7in. globe. Of course, the apartment generally would be adequately lighted as well.

Notwithstanding the apparent loss of light due to absorption by the material of the shade, the useful illumination of any object in the immediate vicinity of such a shaded light will be greater than if the bare mantle or a mantle behind clear glass were employed; by reason of the increased perceptive power of the eye in consequence of the larger opening of the iris.

[NOTE.—The subject of "Shades and Reflectors" is treated comprehensively by Messrs. J. G. Clark and V. H. Mackinney, in a paper published in "The Illuminating Engineer" for March, 1913.]

Shop Lighting.

THERE is much scope for both science and art in the lighting of shops, warerooms, and commercial interiors generally. Shop-front and window lighting is a study in itself. The first point to be noted in any such application is the particular kind of effect required to be produced; which usually depends upon the class of business in the case. After this comes the amount or scale of the illumination desired, whether for actual use, or for display and trade rivalry. Not all shopkeepers seek a brilliant lighting scheme. In certain lines of business there is more attractiveness in a quiet, reposeful scale of illumination; which need not look poverty-stricken. Old furniture, ancient houses of call, and so forth offer scope for careful lighting which shall be adequate without being too clamorous. With the powerful illuminants of the present day, it is easier to overdo lighting than to keep it within the bounds of artistic propriety.

In artificial, as in natural lighting, a very large range of illuminative strength can be tolerated by the vision. What helps to the perception of objects more than the actual brilliancy of the lighting, is their differing reflecting power, variety of colour, and relative movement. In practical shop or display lighting the last-named aid to perception is ordinarily not available, otherwise than in the matter of flashing signs. It is arguable that the stillness of incandescent gas lighting may be for some purposes a disadvantage, as compared with the liveliness of a lavish flat flame display.

It is certain, however, that for purposes of perception only, a low scale of illumination may be quite as useful as a high one; whereas when the element of display has to be considered, as in the case of rival shops in a commercial centre, a superfluity of illumination will find a ready market.

For example, provision shops open to the street can

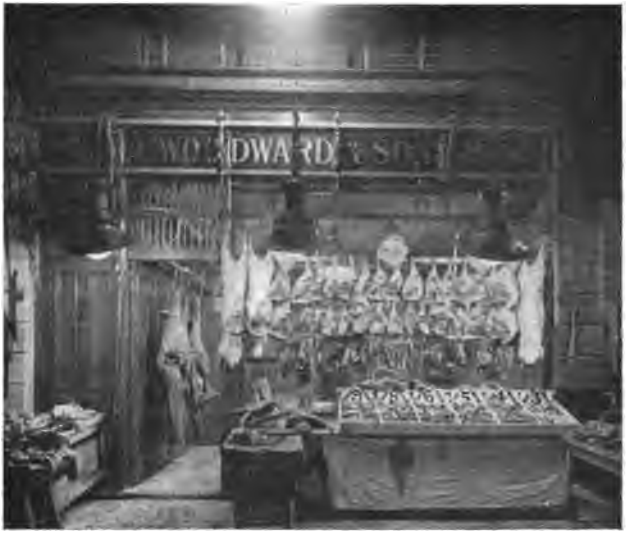


Fig. 24. HIGH-PRESSURE GAS LIGHTING (BUTCHER'S SHOP), BY HANGING OUTSIDE LAMPS.

hardly be too well lighted in front (Fig. 24). Meat, fish, fruit and eggs light up well; and for this purpose a row of high power outside lamps, high or low pressure as may be available, can be aligned at the level of the facia, or not lower than 8ft. 6in. above the pavement. In many districts this service is undertaken by the gas authority at an inclusive rental, not by meter. It is then independent of the interior service. Many prefer 3 or 4-mantle low-pressure high-power lamps to high pressure lamps for this work; and it is certainly easier to serve scattered groups of shops by the former means.

For a special evening shopping promenade, where the pavement is sufficiently wide, a row of fairly but not too brilliant lamps at the curb line is attractive; and some leading establishments will be distinguished

A Brilliant Show at a Kensington Corner.

by carrying the display lighting up to the higher stories and into a turret, if there is one. Showy frontages pay for lighting up; and even plain ones can be rendered by judicious illumination more imposing after dark than in daylight.

There is a large class of retail shops which lend themselves to the "ramp" system of window lighting; this means confining the lights to a row placed high up, above a glass plate covering in the contents of the windows.

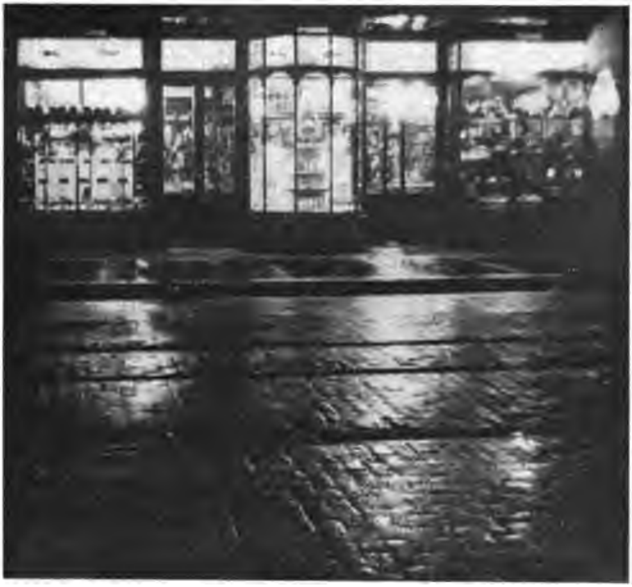


Fig. 25. "Ramp" Lighting, Low Pressure Gas, of a Confectioner's Shop.

Inverted Lamps under silvered reflectors, behind a stained glass ventilated facia. Sheet glass enclosing window underneath lamps. Pneumatic distance ignition. Shop also warmed by Gas-steam Radiator standing in middle of floor. Interior perfectly sweet and attractive at all seasons.

The light is reflected downwards and has a specially brilliant effect upon bright coloured goods, such as sweets, silver ware, and most articles ordinarily displayed in a window casing of no great depth. The system has the advantage in some cases, that the burning gas is kept entirely out of the window; which should be well ventilated above the facia.

It makes a great difference in the appearance of such a window how the wares are arranged in regard to the light. Obviously, a boot or a clothier's shop will need twice the amount of illumination necessary for a confectioner's; but even so, a much brighter appearance will be secured if the darker articles—black boots, dark cloths—are placed nearest the light, and the bottom of the window filled with white goods. This disposition will help to equalize the illumination. (Fig. 26).

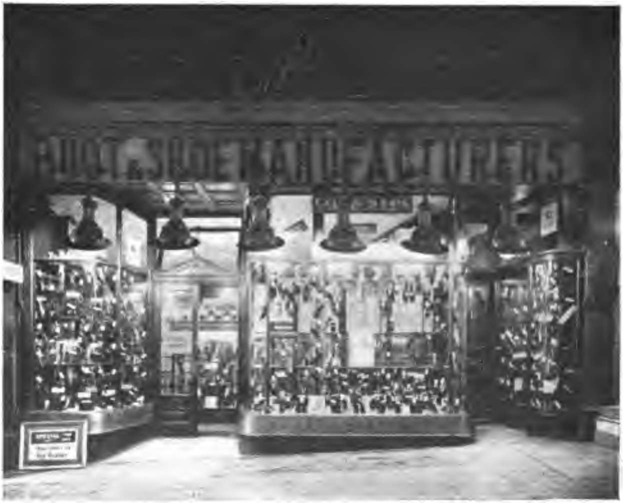


Fig. 26. High-Pressure Lighting (Boot Shop).
Hanging lamps outside, Inverted low-pressure lamps inside.

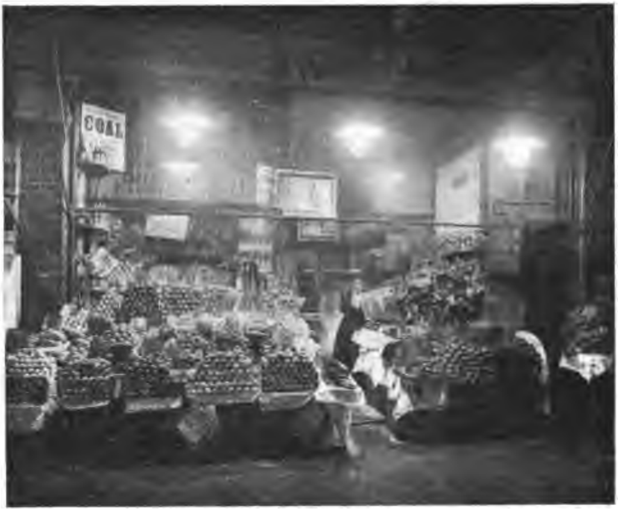


Fig. 27. High-Pressure Overhead Lighting of an Open Fruit Shop.

Some shops, being dressed close up to the glass, have no apparent depth and must be lighted wholly by hanging lamps outside, provided with angular reflectors for the purpose. The reflectors should be set at an agle of 45° with the vertical, and be brought as low down and far off from the glass as possible.

The old-fashioned temporary emplacement of such lamps is now obsolete for ordinary shops; but a good trade is done in the removable lighting by high-power lamps of street and market stalls (Fig. 27).

Shops of considerable depth of window, as large drapers' and furniture warehouses, are best lighted by pendants, or ceiling ventilating lamps of power according to requirement.

Restaurant frontages, and sometimes bakers' windows, are liable to get steamy unless ventilated to a degree which may be regarded as uncomfortable by the occupants. This annoyance can be prevented by slightly warming the glass, by means of a few small flat flame burners along the bottom; or if an addition to the lighting at this level is desired, by upright incandescent burners in opal "normal" chimneys.

In most shop lighting, the entrance doorway calls for special treatment, so that its situation shall be conspicuous. It is in general desirable that on entering the illumination of the interior shall not show a falling off from the outside invitation; although inner recesses may well be lighted more restfully, but by no means poorly. Plenty of light also connotes cleanliness; which is a great recommendation. No shop lights should be lower than 8ft. 6in. from the floor; and whatever their power (which will be determined by the requirement of the trade) should be spaced no wider than their own height apart. This will ensure an equal diffusion of the light.

An Illustration of the Art of Lighting, as exemplified in the case of a Public Hall.

THE art of lighting is to the science of the subject what the masterly use of tools is to the manufacture of them. A little of the science of the measurement of illumination effects is easily picked up, and might earn marks in a paper examination; but alone it would not enable its possessor to design a satisfactory plan of lighting on a considerable scale. After all, this kind of science is only mathematics; and therefore cannot produce more than is put into it. Good artificial lighting is a work of art. It has to be based upon science, of course, in the sense of being correct on the main points of adequacy, economy, safety and practical convenience. Good sense and good taste are also necessary to make a sound job, lacking which the result cannot be pleasing to the eye and satisfactory to the sense of fitness.

The truth of this view of artificial lighting will appear from a glance at the accompanying diagrams, which show three different ways of solving the practical problem of lighting a public hall. The hall is supposed to be 60 feet long, 35 feet wide, and the ceiling is 25 feet high. The lighting is to be of the first order of brilliancy, suitable for a ballroom. The walls and ceiling are pale tinted, or white, with a reflecting power of about 60 per cent. of the quantity of light falling upon them. The most artistic, generally pleasing, and dignified way of providing the required amount of light is according to style A, using eight large incandescent gas lamps of 10 cubic feet hourly consumption. The eye will not seek these lamps, although conscious of their existence and position. They are like good servants, neither in the way nor out of the way. The distribution of the illumination works out to very near equality of diffusion. Every unit, at a technical efficiency of 30 candle-power per cubic foot of the hourly gas consumption, represents a luminosity intensity of 300 candle-power. This is reduced 45 per cent. by opal shades, leaving 165 candle-power available in all directions. One of the compensations for the heavy nominal loss by transmission through milky glass is the equalization of the polar distribution; so that we do really get a globe, or globes, full of soft white light shining with equal power all around. It can also be looked at without dazzling, which means that the iris of the eye is not distressed by incessant play of the accommodation. Hence the modulation of the crude intensity of the mantle variation is not all loss.

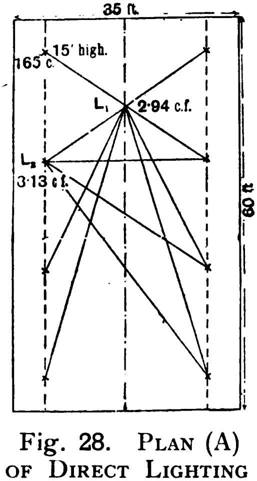


Fig. 28. Plan (A) of Direct Lighting for a Public Hall.

Starting, however, with a unit working at an intensity of 165 candle-power, 15 feet above the floor, it is necessary to remember that the effect of the reflection from the white ceiling and light-coloured walls will assist the general illumination by at least 50 per cent. upon this figure. It is evident that the spot on the floor which receives the smallest quantity of light is at the mark L_1. Adding the effects of all the units, which radiate upon this spot from their respective places, the total illumination here amounts to 2·94 candle-feet, or, say, just under 3 candle-feet. Similarly, the brightest spot will be just underneath one of the lamps, as at L_2; which shows a calculated illumination of 3·13 candle-feet. Thus the distribution is equal, within the range of experimental observation. The particular disposition of the lamps in this case (as large single units) is governed by the general uses of the hall. If it is to be occasionally used as a lecture room or place of entertainment, with a platform or platform placed against the end or side walls, it is better without axial lights, which get into the line of sight. On the other hand, if it is to have no other use than that of a ballroom, the main lights should be axial; because the greatest brilliancy is wanted in the middle of the room. In this case the major units would be best in the form of pendants of many lights, instead of the severe single large units, which answer the purpose of a lecture hall well enough.

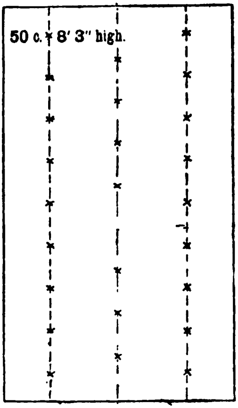


Fig. 29.
SAME, MODIFIED (B)

Turn from style A to style B (Fig. 29). The science is the same in each case. There is so much light required, and it can be provided quite well in this way. But who would choose it? There was once a long corridor, or hall, lighted after this pattern by incandescent electric lamps, at one of the South Kensington exhibitions. The effect was trying in the extreme, and nobody lingered there.

The third illustration, style C (Fig. 30) is a stage between the two others. It would be quite suitable for a store or warehouse, being cheap to carry out in double-mantle lamps. It is not very restful, however, for people sitting down doing nothing. The purpose in sketching these illustrations is to show that in the selection of styles of interior lighting the controlling influence is taste, which is undefinable. It may be hinted at, possibly, by saying that the power and spacing of the light units depends upon the size and character of the interior; but this dictum does not furnish any guide to a decision that can be relied upon to produce a satisfactory effect in all circumstances. One thing is certain—that the infinite gradations and varieties of incandescent gas lighting units are far more conducive to the realization of a satisfactory result that the limitations of electric light to units which are either too big or too little; or if applied in a "shadowless" method are apt to produce a depressing effect.

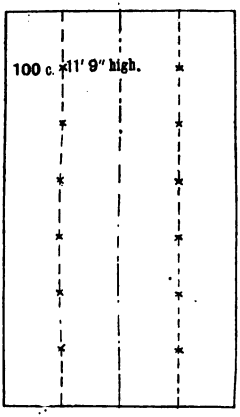


Fig. 30. SAME, FURTHER MODIFIED (C)

Factory, Workshop and Yard Lighting.

By way of introducing this branch of the general subject, the author ventures to give the following extract from a lecture delivered in connection with the National Gas Exhibition, 1913.

" Vast as the general advantage of modern improved gas lighting has been in every department of the advance from the old flat-flame standard of illumination, both for exteriors and interiors, in none has it proved a greater boon than in the busy centres of organised labour. In technical language the term " illuminating power " is employed as a measure of what used to be regarded as the " quality " of the gas, which has no meaning except to the gas manufacturer. It is a laboratory standard merely. There is another sense in which the same term may be employed, within the comprehension of plain men—namely as a definition, loose yet intelligible, of the range of illuminating capability of any sort of artificial light. I venture to perpend the idea as a workable conception of the real measure of the availability of an artificial light for seeing by; that is to say, it is what inspires the act of a man who strikes a match to look for a small object dropped upon the floor, or to catch a glimpse of a near thing in utter darkness.

" The temporary gleam of a match is sufficient for the object in view; and so is a candle, a torch, and a fire " devil " of glowing coke. From these primitive lights up to a " Lucigen " flare lamp, an electric flame arc lamp, or a high-pressure incandescent gas lamp is merely a question of steps in illumination resource, which should be trodden by the feet of recognised need. The latest word of artificial lighting technique is that no limit can be assigned to the power of artificial illuminants. The corresponding word of illuminating engineering science ought to be to fit the available means to the end. If we are told what is exactly the requirement that is to be satisfied, there is no shortcoming of illuminant power available for the purpose on the gas side.

"The luminous intensity of any artificial illuminant and its usefulness for any practical application are two different things. It does not by any means follow that because a candle in a lantern is capable of being put to excellent use, therefore a light of 100 "candle-power" must be a hundred times as good. Similarly, it is absurd to argue that luminous intensity alone, measured in terms of "candle-power" is any indication of the true utility of a source of artificial light.

"The reasonable requirements of every case must be consulted in any satisfactory scheme. This sounds like a truism; but experience shows that there have been many attempts to fix up the lighting to suit the lamp, instead of suiting the lights to the requirement. Perceptivity is the test of suitable lighting, especially of interiors and yards where work is carried on. It is claimed that good lighting increases the productive capacity of men and machines; and doubtless this is true, if properly understood. The lavish employment of powerful lights is not necessarily good lighting. We can fit up a factory with gas lamps measuring 3,000 candle-power, if desired; but we should not recommend such intense units for general use, much less insist upon making a speciality of them, as we might be tempted to do if they constituted our whole stock-in-trade.

"As this is privileged ground, I do not shrink from stating why factories and workshops are better served by gas light than by any other means. In the first place, as regards the scale and scheme of any lighting job—meaning by the first expression the degree, and by the latter the style of the service—gas alone can be had in units of any power, from the same supply. Gas will serve for the safety flat-flame lights of stable yards, exits, cellars, danger spots, etc. It is equally available outdoors and in. It is steady, reliable, does not hurt workpeople's eyesight, and is cheaper than any other illuminant equally available. It is not only less expensive, light for light, but it is cheaper to instal and maintain, and the skill required for attendance is moderate. Everything about it is within the capacity of an ordinary mechanic to look after.

“The comparison of the working cost of gas light in a factory or workshop is not with flame or open arc electric lamps, which are unsuitable for the purpose; but with metallic wire incandescent electric lamps, as to which it is claimed that the latest will give an average of a candle-power of light for every half-watt of energy. If it is assumed that the most convenient lighting unit for the job is 600 candle-power lamps, and granting the electrical efficiency named, this means an hourly consumption of 300 watts per lamp; say, about three such lamps should run to a Board of Trade unit of current per hour. It is hard to know at what price to quote the unit, for a mean example, because some electricity undertakings appear to prefer to give their commodity away; which gas undertakings have not yet found it necessary to do. A fair profit charge would be about 3d. per unit. The estimate on this basis would therefore be as follows:—

Electric Light:—

Per 600 candle-power Tungsten wire lamp, at a reputed (unproven) efficiency of half-a-watt per candle-power, for 1,000 hours current 300 Board of Trade units, at 3d.	£3	15	0
Maintenance (estimated)	£0	10	0
	£4	5	0

Gas Lighting:—

Per 600 candle-power high pressure inverted lamp, proved efficiency, 60 candles per cubic feet consumption for 1,000 hours, 10,000 cubic feet at 2/6 per thousand	£1	5	0
Maintenance	£0	3	0
	£1	8	0

"Of course, the selection of the most suitable size of lighting units, their elevation and spacing, must be decided with regard to the conditions. For general workshops, foundries, etc., a simple rule is, one 600 candle-power lamp (at the height of 8ft. 6in.) to every 300 square feet of the floor area. If higher lamps (to clear travellers) must be used, the power of the lamps must be raised in proportion to the height in feet *squared.* Fortunately, gas light is so cheap and its installation so simple that actual experiments can be easily made on any scale. The choice is open as betwen high pressure, ordinary main pressure, and air pressure systems. On wide grounds the preference falls upon the first named, for a variety of reasons. A public high pressure supply can now be had in many places; as to which local enquiry should be made, because even where it is not already done, a good enquiry may stimulate the enterprise. On the other hand, no factory need be deprived of the manifold

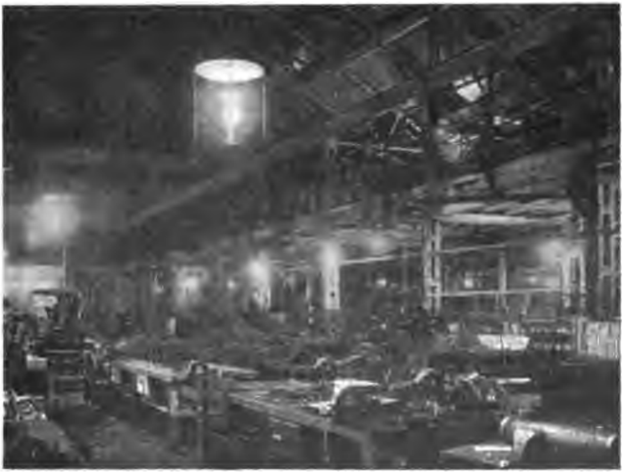


Fig. 31. HIGH-POWER LIGHTING OF ENGINEERING WORKS, DIRECT OVERHEAD LAMPS.

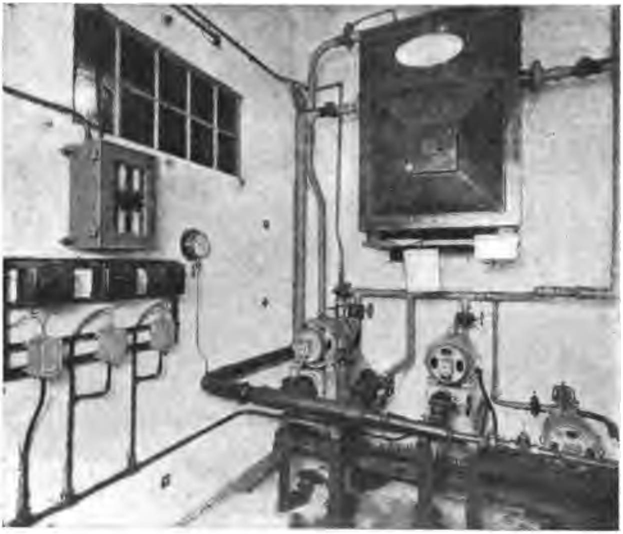


Fig. 32. ELECTRICALLY-DRIVEN PRESSURE-INCREASING PLANT, FOR PREVIOUS EXAMPLE.

The Gas, taken through a meter at the main pressure, is raised to 80 ins. water pressure. The capacity of the two small compressors is equal to that of the largest; which is capable of supplying the maximum demand.

advantages of a high pressure gas service; which are not limited to lighting, since the actual mechanical pressure-raising is a bagatelle, costing under 1d. per thousand (Figs. 31 and 32). Not to go into details, the argument for high pressure gas is that thereby we have it completely under control. Many consumers find the ordinary main pressure supply more available; and it is true that excellent lighting can be had by this system also. It is more a question of height and spacing than of any particular distinctive quality of the light of either system. Where travelling cranes or tall machines have to be negotiated, the lights must be very high up, and then they can be as powerful as you please, and placed thickly. It is a truth not always known or regarded that for equable, non-trying lighting, the more powerful the lights, the loftier and thicker they must be hung. For the ordinary machine shop, 15ft. to 20ft. high, 600 candle-power lamps will usually be powerful enough, spaced about one-and-a-half times to twice their height. The tendency of modern opinion in these matters is to raise the standard of lighting all round. With gas the cost is no consideration to set against the increased efficiency and amount of turn-out, where the lighting is good. For some purposes it is an additional recommendation that the colour of intensified incandescent gas light is the nearest amongst all artficial lights to daylight; nor is it difficult, in the case of town workrooms in narrow streets, to have every hole and corner of the interior brighter than by daylight. This is specially important for clothing factories working upon black material. Air pressure lights are very useful for dusty atmospheres, as the lamps can be supplied with clean air from outside. Although the "glare" of a light can be removed from the sight of workers by elevating the lamps well above the customary line of vision, it is sometimes impossible to effect this; and then the lights within the field of vision should be shaded by opal or ground glass, if powerful; or if not over, say, 100 candle-power intensity, by backing with a clean white matt surface—a white-washed card is as good as anything more expensive. The question of supplementing the general lighting of the shop by small local lights close to the workers or their tools, is one to be solved by carefully consulting the workers themselves, and conforming to what they may be accustomed to, unless it can be improved upon. No hard and fast rule can be laid down for these cases, which refer mostly to fine work. Strong local lighting, as of sewing machine heads, or printers' "cases," calls for particular care in shading, so that while the light falls upon the right place the luminous source itself is hidden. On general principles, concentrated local lighting ought to be accompanied by adequate distributed lighting; because nothing is worse than the eye-strain caused by glancing from bright places to dark spaces. Especially, all factories and workrooms should be well white-washed all over as frequently as the particular conditions require, in order to assist the lighting as well as for sanitary reasons.

"The matter of Factory and Workshop Lighting is treated in the Annual Reports of the Chief Inspector of Factories and Workshops for 1911 and 1912, by Mr. D. R. Wilson, and a Departmental Committee is enquiring into the whole subject. I must refer those desiring further information to these sources, and the reported Transactions of the Illuminating Engineering Society."

Public Street and Promenade Lighting.

THE matter of public street lighting divides itself into two distinct provinces, whereof one includes the ordinary administrative lighting of public highways and by-ways as part of the service of public security, and the other embraces the illumination of promenades, boulevards, outdoor places of public resort, approaches to important public buildings, railway stations and depôts, much-frequented wharves, landing stages, quays, etc.

Much confusion and misunderstanding has arisen from neglect to distinguish between these orders of outdoor public, or semi-public lighting. The dividing line between them is really the applicability or otherwise of an illumination standard. There can be no question of measurable illumination of the whole of the roadway, in regard to 95 per cent. of the public street lighting chargeable on local sanitary rates. The common public street lamp, which in rural districts is not lighted at all during the summer months, and may not be lighted during moonlight nights (by the calendar) at other seasons is not for illumination, but for wayfarers' guidance, and police protection. In another connection the author once endeavoured to "place" the universal public street lighting in relation to the civic system, as follows:—

"The 'country' has been defined as 'the parts beyond the street lamps.' The first intimation to the wayfarer of his approaching a town is the far-flung public lamp, which he will notice on the top of a hill, opposite a side road, or subtly linked with some other topographical feature. Even when nothing of the kind strikes the eye, and the first lamp merely appears in its place because it must be somewhere, its influence upon the foot passenger, the motorist, or the waggoner is potent all the same. It is not 'lighting' at all, in the same sense as that in which the word applies to the use of gas in interiors; but the meaning is that conveyed when we speak of a well-lighted coast line. . . . . Therefore, powerful lamps are quite out of place in these outskirts of towns; where, indeed, they are only an annoyance to drivers and a nuisance to the owners of adjoining property. What is best appreciated is an adequate number of ordinary incandescent gas lights, of a luminous intensity of from 80 to 100 candle-power; kept clean and in good order, and regularly spaced in sight of one another—that is to say, not more than eighty yards apart where there are few houses and no cross-roads."

The design and construction of the lamp-post and lantern are important considerations. One standard pattern should be selected and adhered to, for the sake of facility and economy of maintenance. Lamp-posts and lanterns are usually the property of the local authority; who should have a renewals fund for wiping out old stock. Inverted burners are preferred for both economy and serviceability; and even where ignited by hand, flash-light ignition is better than the torch, which involves risk of rough handling.

Lanterns for general purposes should be of the square pattern, glazed in copper frames, with slightly convex porcelain top reflector. Simply decreasing the distance between the lamps gradually converts "beacon" street lighting into "illumination." Circular lanterns are preferred for principal thoroughfares, with one, two or three mantles; some of which can be put out of action at midnight.

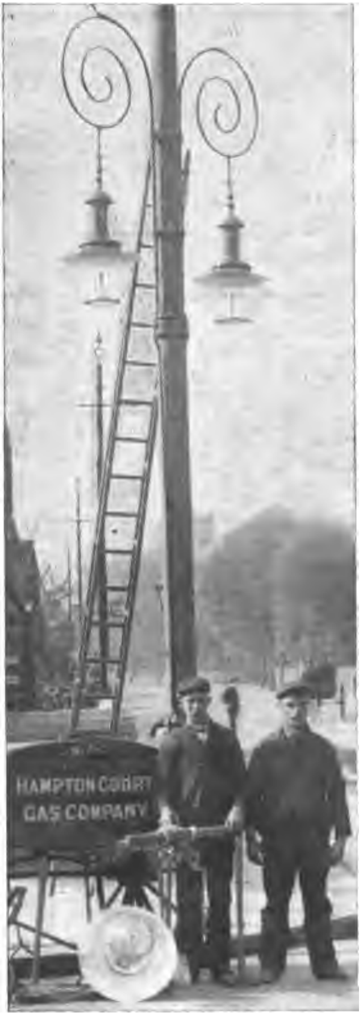


Fig. 33. TRAMWAY TROLLEY-WIRE POST FIXTURE, FOR LOW-PRESSURE PUBLIC STREET LAMPS.

Small public street lamps should be 12 feet above the pavement line.

Along tramway lines lamp suspension to the overhead trolley posts by a springy attachment is a way to save additional obstruction of the side-walk (Fig. 33).

When the key of the public street lighting is raised to a pitch of actual roadway illumination, it is expedient to suit the power of the lamps to the width of the street between frontages. Generally speaking, the kerb position, with the lamp column standing well back, is the most suitable for both vehicular and pedestrian traffic in the case of the highest class and busiest thoroughfares up to 80ft. width. Refuge lights must then be added.

For this width it is the best policy to decide upon units of ample power. Nothing less than 1,000 c.p. high pressure inverted lamps for the main lighting and 1,500 c.p. for crossings and refuges should be entertained, on suspension columns 18ft. to 21ft. high. For narrow thoroughfares the lamps may be hung over the side-walks from boldly-projecting brackets; or in extreme cases suspended by traversing gear over the middle of the roadway. It is to be observed that increased candle-power of lamps does not enable the horizontal spacing of the lighting points to be increased. Rather the contrary, if "spottiness" of effect is to be avoided.

Although the highest power of public street and other outdoor lighting may realize a degree of diffused illumination of the same order as that observable in interiors and therefore be susceptible of being measured by the lumeter, it is not practicable to apply the test of such measurement for other than the purpose of a check observation. Proposals have been made for basing street lighting contracts upon a specified illumination measurement on the spot; but the exposure of observations of the kind to interference by unpropitious atmospheric conditions robs them of critical value.

It is fairer to specify the minimum luminous intensity of the units chosen for such lighting schemes, at, say, two important angles. In the example of the City of Westminster street lighting contract the following condition as to testing obtains:—

"Each lamp is to be fitted with burners, mantles, globes, and fittings, as the case may be, giving a minimum of 90, 180, 1,800, or 3,000 standard candle-power respectively, as directly measured by an approved portable photometric apparatus placed at ground-level, and is to burn 3,940 hours per annum in accordance with a daily schedule to be hereafter supplied by the Local Authority. The fittings and lamp must be in every respect to the approval of the City Engineer, and in particular the reflectors above the light are not to be concave to the light so as to concentrate the illumination at the foot of the lamps, but horizontally flat or slightly convex as approved by the City Engineer, so as to disperse the rays. The tests will be taken in such a manner as to ensure that glazing bars shall not interfere with the results obtained. The candle-power shall be arrived at by taking the average of two readings in any position with regard to the light under test—one reading at an angle of 20°, and a second reading at an angle of 50° to the horizontal." * (See Fig. 23.)

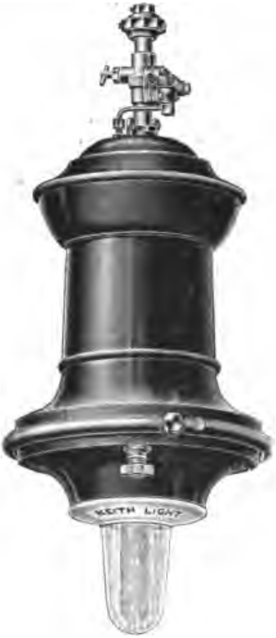


Fig. 34. THE KEITH SILICA GLOBE LAMP.

This Lamp, at the time of writing, is the highest-class increased pressure gas lamp in use. It works at a pressure of from 80 ins. to 100 ins. of water; and develops quite 60 candle-power per cubic foot of gas. The silica globe is proof against shocks and douches of water. All the air of combustion is taken in as "primary." Bulk and weight are saved. The silica does not require cleaning; thus maintenance costs are reduced.

[* NOTE.—These measurements can be conveniently and accurately made by means of the Simmance-Abady Patent Street Photometer, made by A. Wright & Co., Westminster.]

Automatic Ignition of Public Street Lamps.

The automatic, or more strictly speaking, mechanical ignition of public street lamps is growing in favour. The idea has a long history, the gap between the obvious suggestion and the successful accomplishment proving difficult to span. Mechanical ignition and extinguishment aims at economy of both labour and gas. In a fairly well-lighted district hand lighting and extinguishing may be able to deal with from 85 to 100 lamps in about an hour. Instantaneous ignition and extinguishing effects a saving of 400 hours' lighting a year over handwork.

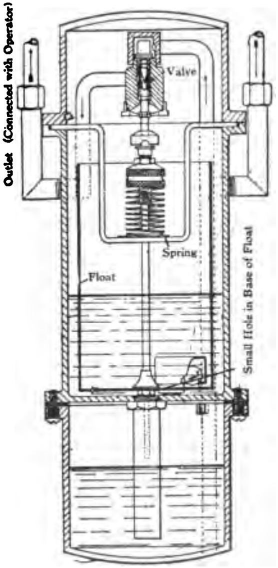
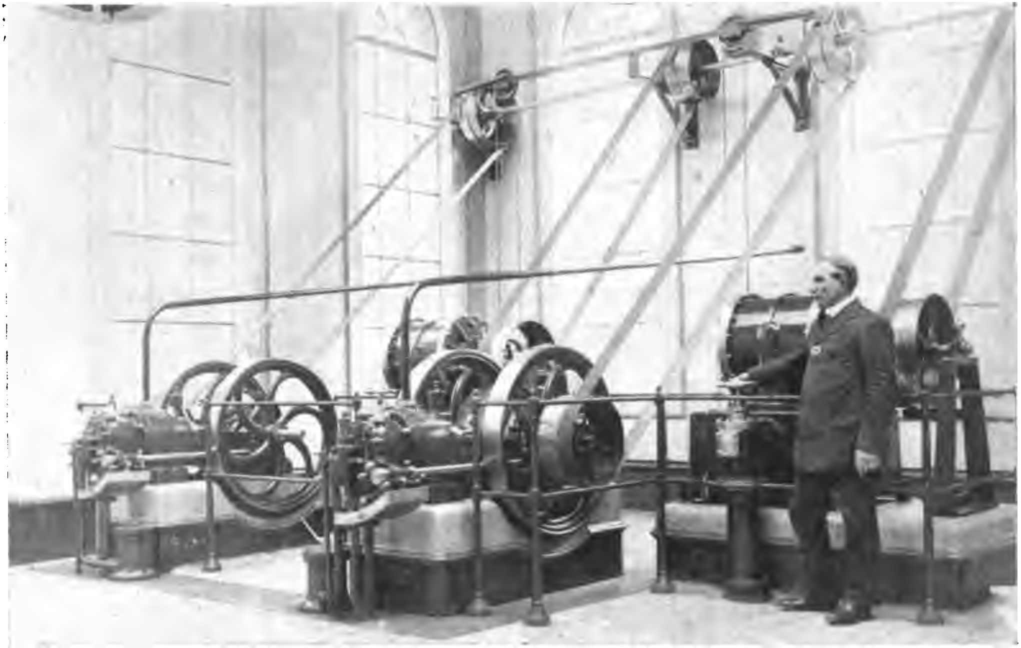


Fig. 35.
The "Broadberry" Public Street Lamp Pressure-wave Igniter.

Chemical methods having failed, the operations are effected by "pressure-wave," clockwork, and electrical systems. The first-named principle is the most obvious, inasmuch as already a gas main network offers all the elements of a pneumatic signalling plant. It appears easily possible by increasing the gas pressure temporarily to directly effect the opening or closing of a valve in the lamp connection; but in practice this operation cannot be ensured all over a wide area, and if the most remote lamp cannot be controlled the whole arrangement must be condemned.

The Rostin apparatus acts by the ordinary increase of pressure for the night consumption, any chosen amount unsealing the admission of gas to a small holder fixed in or near the lantern, which in turn actuates the burner cock. The same increment of pressure extinguishes. This device acts quickly, and the cock is moved with considerable force. Mr. A. E. Broadberry has improved upon the idea by overcoming the liability to accidental movement. (Fig. 35.) The controlling element is a float with a small hole in the bottom, in connection with a reservoir of mixed glycerine and water, which does not freeze. A sharp increase of main pressure of about 8-tenths will lift the float and operate the lighting or extinguishing movement of the Operator, whichever is in order. A gradual alteration of pressure merely causes the fluid to rise in the float through the small hole, and effects nothing. Thus the apparatus works irrespectively of ordinary main pressure variations. The "Bamag," Alder and Mackay, and several other pressure wave systems are also in successful use. The great advantage of the principle is its flexibility. In the event of a sudden fog the lamps can be lighted immediately, and need not be put out until a convenient time.

The "Horstmann" gas controller was perhaps the first successful clockwork and truly automatic apparatus. It is quick in action, which is desirable with incandescent lights, and is adjusted to the varying length of the night. The saving of the pilot light consumption during the hours of lighting is a feature of some of these devices; of which a new one is brought out every six months or so.



A Section of the Gas Pressure Raising Plant, Horseferry Road (The Gas Light & Coke Company).

The Bunsen Burner; and Gas regarded as a Fuel.

It is expedient at this stage to consider the bunsen burner, which has been mentioned as the agent in applying the heat of the gas flame to the Welsbach mantle. But for this device not only would there have been no incandescent gas light, but the applications of gas as an industrial and domestic fuel would have been very restricted. The indebtedness of the Welsbach light to the bunsen burner has been repaid by the more thorough knowledge of the principle of the latter, which its adaptation to this special purpose has brought about.

It is hardly possible to discuss the burner which is chiefly associated with the use of gas as a fuel, without taking into consideration the fuel aspects of gas as well; because although, as Lewes has well remarked, "if no method had been devised for burning coal gas with a non-luminous smokeless flame, little or nothing would have been heard of coal gas as a domestic fuel," nothing could have been possible either if the gas itself had been destitute of the essential qualities of such a fuel.

It is necessary to explain these qualities and to distinguish the part played by the bunsen form of burner in their application.

In entering upon the study of gas as fuel, we at once find ourselves in different circumstances from those affecting its use for lighting. Whereas the illuminating capability of gas is to a very great extent conditional, and is largely governed by the manner in which the gas is treated: Also, whereas the effect is very variable, and has no apparent limitation—the power of gas as a fuel is known, is limited, is governed by its composition, and is practically independent of the methods in which it may be burnt.

The calorific power of gas is expressed in British Thermal Units (B.Th.U.). Such a unit represents the amount of heat required to raise the temperature of a pound of pure water 1° Fahrenh it, say, from 59°

to 60° Fahr. In burning completely to carbonic acid gas (CO_2) and water (H_2O), a cubic foot of common town's gas will give out from 500 to 600 B.Th.U. of heat, according to its composition.

In practice, the determination of the calorific power of a solid or a fluid combustible is effected experimentally by burning a weighed sample in an apparatus in which the heat of combustion is absorbed by a known quantity of water. Sometimes pure oxygen is substituted for air in this operation, to ensure the complete and rapid combustion of the whole sample. In the case of a gas, a special procedure is necessitated by the form of the combustible; which is therefore burnt in air by means of an ordinary burner, inside an apparatus resembling a "geyser," or the instantaneous gas water-heater of commerce. In order to absorb all the heat of combustion, the flow of water in the jacket of the gas calorimeter is adjusted so as to absorb the whole of the heat of the products of combustion, down to the temperature of the surrounding air. An incidental effect of this arrangement is that the water formed (as steam) by the combustion of the hydrogen of the gas with the oxygen of the air is condensed within the apparatus, and in collected and measured. The quantity of water so formed varies for different samples of town gas, according to the proportion of hydrogen in the mixture. In condensing to water, this steam gives up to the wetted surfaces the quantity of heat which it had stored as "latent," which circumstance is regarded as giving the reading of calorific power, with condensation, an unduly higher figure than the same gas would give in ordinary burning where there is no condensation. Consequently, in laboratory tests for the calorific power of gas the amount of heat represented by the internal condensation of steam in the calorimeter is allowed for, and subtracted from the calorific power shown by the heating of the water by the combustion of the gas. This total effect is termed the *gross calorific power*, and the lower figure remaining after subtraction of the allowance for heat of condensation is termed the *net calorific power.*

Hitherto, in British practice the net calorific power has usually been treated as the proper indication of this quality in town's gas; but the "gross" reading only is taken on the Continent and in the United States, for the very good reason that when the steam of the combustion passes off uncondensed, the other and uncondensable portion of the products goes away with it, and since the loss of heat from this cause is greater than the former loss, the real value of the correction of gross to net calorific power is not worth the trouble of making it.

So far as the practical question goes the same figure must always be used in comparing experimental results. In ordinary working with town's gas a deduction of 10 per cent. of the gross figure from itself will about correspond with the net figure obtained by calorimetric measurement. Gas containing carburetted water gas shows a smaller difference between the two values than a "straight" coal gas.

This so-called calorific power of gas has no necessary connection with the "illuminating power," although a "rich" coal gas will have a higher calorific figure than a low grade gas, whether the latter is all-coal or mixed with carburetted water gas. It is an error to put a particular value upon a relatively high calorific figure for town's gas; because such readings do not truly measure the actual fuel value of the gas, nor take account of the flame temperature. The "richer" the gas the more air it requires to burn it, whether for fuel purposes or luminously (see p. 135).

In practical heating, the real efficiency of the fuel—that is, its economical value—depends chiefly upon the proper proportioning of the air supply. It by no means follows that the highest grade of any form of fuel will prove worth more money than a poorer class of fuel, if it is troublesome to burn, or requires such a large volume of air as to bring the ultimate strength of the burning mixture down to an uneconomical figure, and lower the flame temperature. In the

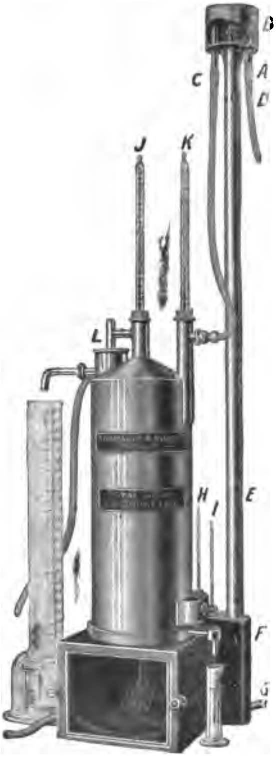


Fig. 36. A "Total Heat" Gas Calorimeter, by A. Wright & Co.

The principle of this apparatus is that the air of combustion is saturated with water vapour, by the same water which is used to absorb the heat of the gas. The water flows from a reservoir B, by the pipe C, into the jacket of the Calorimeter, and also descends as spray in the pipe E; entraining air with it at D. This air finally enters the combustion chamber at F, under a slight pressure, and the waste water escapes at G. Thus the error of other instruments of the kind, which take in air at varying degrees of atmospheric moisture is avoided. I.J.K., are thermometers.

[Note.—Technical opinion is tending towards the adoption of the gross or total measure in all cases.]

burning of solid fuel for steam raising, etc., it pays to give attention to the volume of air admitted into the furnace. Instruments are used to continuously test this factor of economical working, by recording automatically the proportion of CO_2 in the flue gases; as it is found that a large excess of air above the amount required for the complete combustion of the fuel is very wasteful.

Obviously, in the burning of such a fuel as gas, which so readily mixes with air and is all flame, the effect of a wrong proportion of air for combustion must be more immediate than in the case, say, of coke. It is immaterial to the total heating effect of a gaseous combustible whether the necessary air of combustion is brought into contact with the flame *after*, or, as is often more convenient, is mixed wholly or in part with the gas *before ignition.* The total amount of heat produced is the same with any method of burning; but the flame temperature may vary.

The true measure of the heating strength of a fuel is not the "calorific power" of the fuel, regarded alone.

Consider, for example, a sample of town's gas testing in the calorimeter to a net calorific figure of 600 B.Th.U. per cubic foot. Such a gas might require, say, 6¼ times its own bulk of air to completely burn it. In the act of combustion, therefore, the calorific power is spread over a total burning mixture consisting of (gas 1 volume + air 6¼ volumes) = 7¼ volumes of mixture. Dividing the calorific power by this number, $\frac{600}{7\frac{1}{4}} = 83$ nearly; which is the calorific power of a cubic foot of the combustible mixture.

Consider also another sample of gas, showing a net calorific power of 500 B.Th.U., but requiring only 5 times its bulk of air for combustion. Then dividing as before we have $\frac{500}{5+1} = 83{\cdot}3$ B.Th.U. per cubic foot of the mixture.

So that the available strength of both samples of gas as fuel is practically the same; although the cost of the "richer" gas will probably be considerably higher than that of the nominally "poorer" sample; while the latter will even have the advantage in flame temperature.

The method of arriving at the quantity of air required for completely burning a sample of gas is as follows:—The composition of the sample must first be ascertained by chemical analysis, which will give similar results to the following, in the case of a well-made straight coal gas:—

Heavy, light-giving hydro-carbons ($C_n H_m$)	2·4	per cent.
Marsh gas (CH_4)	31·0	„
Carbon monoxide (CO)	8·5	„
Hydrogen (H_2)	53·8	„
Nitrogen (N)	4·3	„
	100·0	

Candle-power, 15·5
B. Th. U. (gross) 586·3
„ (net) 518·3

According to the chemical tables, the proportion of air per cubic foot required (approximately) for the perfect combustion of these components is—($C_n H_m$) 14·25; CH_4, 9·56; CO, 2·4; H_2, 2·4. Therefore the proportions for the above example would be

$$\begin{array}{llcrcr}
C_n H_m & 2\cdot4 & \times & 14\cdot25 & = & 34\cdot2 \\
CH_4 & 31\cdot0 & \times & 9\cdot56 & = & 296\cdot3 \\
CO & 8\cdot5 & \times & 2\cdot4 & = & 20\cdot4 \\
H_2 & 53\cdot8 & \times & 2\cdot4 & = & 129\cdot1 \\
\hline
 & & & & & 480\cdot0
\end{array}$$

480·0, or 4·8 cubic feet.

Then $\dfrac{586\cdot3}{(4\cdot8+1)}=101$ B.Th.U. (gross), and

$\dfrac{518\cdot3}{(4\cdot8+1)}=89$ B.Th.U. (net) per cubic foot is the strength of the theoretically perfect burning mixture.

One point of immediate importance to the consumer of gas and to the gas fitter, which arises from the foregoing calculation, is that it makes no difference as regards the total heating power of burning gas, *in whatsoever manner it may be burnt* to its ultimate products of combustion (CO_2 and Water). If the gas is burnt in " rat-tail " flat-flames, or argand luminous flames, or in bunsenized (" atmospheric ") flames at high pressure or low, *the total calorific power* remains constant and unalterable.

Although the foregoing conclusion can be logically deduced from the character of the calorimetric process, which yields the same result whether the gas is burnt luminously or bunsenized; and is confirmed by practice with geysers, which are mostly fitted with a number of luminous burners and show a high efficiency in operation; it is far from being generally realised. It is rather a common thing to find gas fitters entertaining the erroneous belief that the bunsen kind of burner gives " more heat " than the luminous flame, and not seldom a maker of " wild cat " gas heating appliances will advertise his wares as being more economical of gas than others because his " patent burner " consumes " more air."

The truth about heating by gas is that so long as the flame is allowed to burn itself out, with sufficient air and no interference, one kind of burner is as good as another for the production of the *total heating power of the gas.*

Moreover, the *temperature* of the hottest part of a flat-flame of gas, which is found on the surface of the upper or luminous part of such flames, is as high as can be produced by any other burner. Therefore, for all applications in which the use of the luminous flame is convenient—as in geysers, where it is preferred because it lights up and goes out quietly; and for small flueless air-warming " stoves " of the reflector or " condensing " patterns—there is no heat to be gained by bunsenizing the gas.

This latter expedient, which means mixing a proportion of the total air of combustion with the gas *before* ignition, is both convenient and indispensable for the greater number of applications of gas as fuel. Its advantages are as follows :—

1. It prevents the deposition of unconsumed carbon, in the form of soot, when a solid body is brought into contact with the flame; consequently the bunsen flame is quite clean in use.
2. It enables the heating of solid bodies to be effected by approximate flame-contact; thus rendering available for use the highest obtainable temperature of the gas and air flame.
3. It enables large or small quantities of gas to be burnt with equally good heating effect : Bunsen flames ranging from rates of hourly consumption of 500 cubic feet down to ½ cubic foot, having the same proportional efficiency.
4. The structure of the bunsen burner itself is simpler and less liable to damage than a luminous flame burner. The point of delicacy in a bunsen burner is the gas nipple, which works in the cold. The whole article is cheaper to manufacture than a luminous flame burner.
5. The flaming size, temperature, and operation of the same quantity of gas can be varied over a considerable range by altering the proportion of air admitted to the bunsen tube as " primary air "—that is, the portion of the air of combustion mixed with the gas previous to ignition.

Ordinary bunsens are designed to work at a pressure of 20 to 25-tenths; but they will bear considerable variations of pressure without losing the characteristics of their flame.

The contrary aspect of the bunsen method of burning gas for fuel purposes may be stated as follows :—

1. The lighting of the burner requires some care, especially if the gas cock is at some distance from the actual burner, or the bunsen mixing tube itself is horizontal, in order to prevent a

"bang" due to the temporary formation of an explosive mixture of air and gas in the tube when the cock is opened; or the ignition of the gas at the nipple, known as "lighting back."

In domestic work these accidents are apt to give rise to grave objections. They should be as far as possible prevented or minimized, by the taking of precautions both in regard to the gas and air fittings; and in handling, consumers and users of bunsen apparatus generally should be warned to have the means of ignition (preferably a lighted wax taper, unless the gas burner is quite small and close to the cock, when a match is permissible) ready, and in place *before* the gas is turned on. They should be taught to know when the flame is burning properly and if not to turn off the gas for a moment, and light it again. The reasons for both "bangs" and "lighting back" should be carefully explained to users of gas heating apparatus.

In the fitting, these defects should also be guarded against. There is no perfect possibility of preventing either by any arrangement of the burner or the connections in common use for gas fires, cookers, or water heaters. Bunsens having wire gauze over the end of the tube or something equivalent thereto are less liable to light back at first, while the gauze, etc. is cold; but open bunsen tubes are more suitable for general heating work, as gauzes get choked up and perish quickly.

The defect of "lighting back" proceeds from an insufficiency of gas in the bunsen tube, due partly to too small velocity of the outward flow of the gaseous mixture, which may be caused by insufficient pressure of the supply or too big a bunsen tube. It may or may not follow a "bang"; and sometimes occurs so quietly that an ear untrained to distinguish the correct sound of the proper bunsen flame may not detect it. Consequently, apparatus may become choked with deposited soot from the lighted jet before the mischief is discovered. "Lighting back" may also occur at a later stage, when the bunsen flame has been turned too low, as the result of a passing draught of air, or a badly-placed gas nipple.

"Lighting back" is therefore due to some defect of the burner or the fitting, or the pressure; and as such is not the user's fault. Some years ago considerable attention was given to this matter amongst gas fire manufacturers, with the result that various complicated horizontal patterns of such burners were put forward as "non-lighting back burners." Good manufacturing practice has now gone beyond this stage, and avoidance of the defect is as far as possible secured for horizontal bunsens by (*a*) observing a proper proportion between the length and bore of the mixing tube and the delivering capacity of the gas jet to suit the air requirement of the gas; (*b*) truly centring the gas jet in the mixing tube; (*c*) observing a correct proportion of the sum of the delivering capacity of all the jets of a burner to the supply at the nipple.

Defects of pressure and irregularities of the composition of the gas supply (due to alteration of the proportion of carburetted water gas, which requires less air) are, of course, beyond the fitter's power to deal with. All he can do is to try to strike the local happy mean with his gas and air adjustments.

2. The bad smell of an ill-adjusted bunsen flame in contact with a foreign body.

This drawback has been so serious in the past that some gas consumers have refused to use cookers with bunsen flames. The peculiarly penetrating acrid odour of a smothered bunsen flame is particularly obnoxious to many. Strange to say, it has not attracted much attention from the most skilful masters of gas technics; while stove manufacturers generally have ignored the existence of the evil. Meanwhile, medical opinion has condemned the inhalation of such fumes by workers as conducive to anæmia, loss of complexion, and other ills.

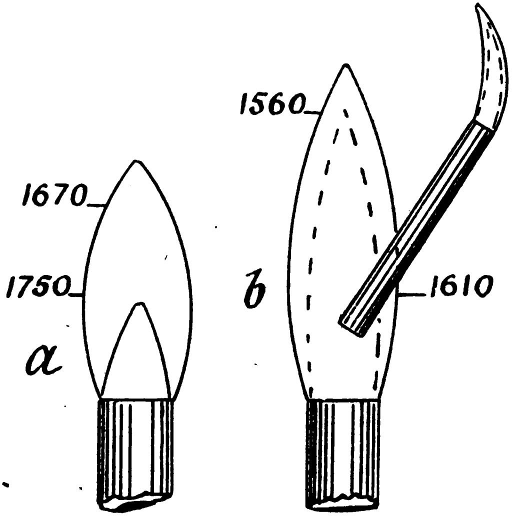
Happily, the defect is merely due to ignorance of the proper manipulation of the bunsen flame, and can usually be avoided by the exercise of a little knowledge and observation, except in the case of some obsolete patterns of gas cookers and heaters, which should be condemned.

The gas fitter must never take for granted the correct adjustment of the boiling or oven burners of any gas cooker or other apparatus drawn from store; as accidental derangement of the gas and air adjustments may occur even when these have been correctly made in the first place; which is hardly to be expected in view of the wide differences of composition of different town gas supplies. It should be borne in mind that a factory for manufacturing gas appliances, situated in a district supplied with 16 to 19 candle-power coal gas has no means of testing the burners sent out to fill an order from a 14 candle mixed gas district. All such apparatus, therefore, should be made adjustable, *particularly for primary air*, and it is for the local gas fitter to make the necessary adjustments for the conditions prevailing in his particular district—that is, for the composition of the gas and the pressure of the supply on the job.

Returning to the question of evil-smelling bunsen gas flames, the cause of this is the *smothering of a hollow flame.* The meaning of this explanation will appear on examination of the accompanying diagrams of a gas flame in different stages of bunsenization. (Fig. 37.)

The flame of burning gas is in active combustion only at its surface, where the air is entering into combination with the gas. This fact can be demonstrated as shown by repeating Faraday's famous experiment upon a candle flame.

This experiment proves that flames have a hollow structure. When a flame of luminous gas is brought into contact with a non-inflammable foreign body, such as a plate of iron, part of the flame is extinguished by chilling, and the gas gives up its carbon in the form of soot, part of which is deposited upon the plate. The altered and extinguished smoky gaseous matter escapes into the atmosphere.



FIGURES 37a & b.

Fig. 37a is a diagrammatical representation of a well-aerated or as it is called in practice a " keen " bunsen flame, showing a short, hissing inner cone. The outer flame above this cone is "solid," *i.e.*, no unburnt gases of imperfect combustion can be extracted from it, either by a tube as in b, or by contact with a cold surface. The " soft " flame, b, shows no distinct inner cone. It is hollow throughout, so that not only can evilly-smelling products of imperfect combustion be extracted from its interior; but this part of the flame is quite cool. It is nowhere so hot as the upper part of the " keen " flame; which alone should be employed for " contact " heating.

When a bunsen flame in the first stage of the process—namely, showing a flabby lilac-coloured flame which can be demonstrated to be hollow like a luminous flame—is brought into contact with a piece of iron, forming, say, the bottom of a kettle, it also suffers partial extinction, with the escape of stinking fumes; but without deposition of soot.

Many bunsen burners intended for heating purposes are employed in this stage. A few years ago nobody knew any better. So long as the gas flame was made non-luminous, by the admixture of a sufficient quantity of primary air to produce the lilac colour, it was judged to be a correct bunsen flame. Its hollowness was recognized, but although this was admitted to be a defect (seeing that the whole of the inside of such a flame is cold) no proper way of remedying the condition was known. What were called "solid flame burners" were put upon the market; but these were merely sub-divided flames, of the same structural character as before.

The only modification possible in regard to the structure of a bunsen flame is by altering the proportion of the primary air. When a bunsen flame has been adjusted to any chosen degree of primary aeration no ordinary change of the gas pressure will alter it. That is to say, if the gas and air are set to produce a "keen" or a "soft" bunsen flame at, say, 25-tenths gas pressure, the character of the flame will not be appreciably affected if the pressure should fall to 15-tenths or rise to 45-tenths. The flame would simply be smaller or larger, according to the quantity of gas passing. The reason for this is that the volume of air drawn in varies directly with the velocity of the gas flowing from the injector, which in turn depends upon the pressure (see Table I.); so that in regard to primary aeration the bunsen is self-regulating at ordinary pressures.

The degree of primary aeration is an effect of the relative proportions of the gas and air inlets, the length and size of the mixing tube, and the presence or absence of resistance at the outlet end of the tube.

By continuing the bunsenization, carefully adding air beyond the stage marked by the disappearance of a yellow tip and the appearance of a uniform lilac colour, a marked change is effected in the flame. Very little more air renders the flame stiffer, shorter, with a bright green inside cone. If the addition of air is made gradually, the inner cone will be seen forming within the outer flame—at first barely distinguishable from it in colour, and almost as long. Then it will grow more distinct, outlining the hollow core of the flame, until it becomes a short hissing cone of brilliant green. This is what is called a "keen flame." A little more primary air and it will light back.

The important point to remember is that this "keen" variety of bunsen flame is burning all through in the portion above the top of the green inner cone. Consequently if this part of the flame only is caused to impinge upon a cold foreign body, such as the bottom of a kettle, there will be practically no giving off of stinking gas fumes as with a hollow flame.

Usually, also, in regard to the boiling rings of gas cookers, etc. (which have been the greatest offenders in this respect), it will be found that when the length of the jets of flame is shortened so as to avoid breaking the green inner cones against the bottom of the pots placed on the grid, the flame does not spread beyond the edge of the pot. This limitation is important, as a guarantee against waste, as well as a preventive of the production of the bad smell of unconsumed gas. Sometimes there is a structural difficulty in effecting this adjustment, owing to the fact of the top of the burners being too close to the grid, thus not allowing room for the flames to develop their green cones unbroken. This is bad construction; and the fitter should endeavour to remedy it if possible by dropping the burner lower. Another defect of such burners is that the jet holes may be placed so close together as to prevent the proper access of "secondary" air to the flames; when there will be a bad smell from this cause. If so, every other hole may be plugged.

A fanciful obstacle to the correct adjustment of these boiling burners is sometimes raised by cooks and others, who entertain an ignorant prejudice for having the gas flaming up round the pots, by which they erroneously believe they are getting a more rapid effect. This is sheer waste of gas, besides creating the offensive smell. Unfortunately, the gas fitter can seldom spare the time to demonstrate by actual comparison the fact of water boiling more quickly with the shorter, fiercer flame.

Whether he can gain his point with every one of his customers or not, it behoves the gas fitter himself to work always in the light of knowledge of the rights and wrongs of bunsen-flame practice; which are recapitulated hereunder :—

1. Bunsenizing does *not* increase the total heating power of gas.
2. Bunsen flames are *not* hotter than luminous flames, but are the only means of bringing the heat of gas flame into the closest contact with solid bodies, without sooting.
3. Bunsenizing means mixing a certain proportion of the air of combustion with the gas before ignition. This air is called "primary" air; and any air afterwards required by the bunsen flame in order to complete the combustion of the gas to CO_2 and water is called "secondary air." The quantity of primary air, added to the quantity of secondary air, amounts to the whole of the air necessary for the complete combustion of the gas.
4. A sample of gas requires for its complete combustion one and the same proportionate quantity of air, irrespective of the method of burning. This proportionate quantity of air can be calculated from the composition of the gas, as determined by chemical analysis.
5. No sample of gas can be caused to burn—that is, to combine in combustion with—more or less than its proper proportion of air.

6. The *total* heating power of a sample of town's gas is not affected by the method of burning or the character of the burner

7. The *temperature* of the bunsen flame can be varied considerably by altering the proportion of the air of combustion introduced as "primary."

8. Roughly speaking, when a little more than one-half of the quantity of air necessary for complete combustion is admitted as primary, a sharply defined green cone shows inside the outer flame. This is about as hot and solid a flame (over the green cone) as can be formed with gas at ordinary main pressures, with a plain upright or horizontal bunsen mixing-tube without gauze to check firing-back. It is known to fitters as the "keen" flame. Less primary air gives a longer flame, with no perceptible inner cone. This is the "soft" or imperfect bunsen flame, hollow to the top, cold inside, and giving off a bad smell of half-burnt gases when brought into contact with a cold solid body. Less primary air still, leaves a white tip to the flame. Between extremes there is a margin of suitable modifications of the "keen" and the "soft" bunsen flames, which it is for the judgment of the gas fitter to select for particular purposes.

   For example, no flame can be too "keen" for the boiling burners or the griller burner of a cooker, the noise of such flames being then of no importance; and the shorter the flames the less danger there is of breaking the green cones. On the other hand, for the ovens of cookers it is not expedient for the flames to be too well aerated, because of the danger of striking back through the shutting of the door. Inasmuch as these oven flames are not brought in contact with anything solid, they would answer just as well if not bunsenized at all. In any case, if the gas flame is not required to make contact with a solid substance the degree of primary aeration is immaterial. For gas fires, also, where it is desirable that the flames should be rather long and silent, an excess of primary aeration is to be avoided. The inner cone should therefore in this case be just discernible, since the flame must not be too "keen," or the heat will be too localized.

9. The upper region of a properly aerated bunsen flame, above the top of the green cone, should be regarded as the working part of the flame.

10. The hottest part of a well-aerated bunsen flame showing a green cone is the thin skin of intense combustion which encloses the whole flame. *Kern*, the inventor of the form of upright incandescent lighting burner known by his name, termed this region of the flame "the zone of hyper-incandescence." It is not peculiar to bunsen flames, being present in all candle, oil, and luminous gas flames. Its extreme thinness in these cases and the unsteadiness of the flame, prevent any attempt to make use of this "zone" of intense heat; but this is to some extent feasible with bunsen gas flames. It was Mr. Kern's design to produce a bunsen flame with such a zone fitting his illuminating mantle; and there is every reason to believe that the brilliancy of a mantle, as well as the high temperature of the radiating substance of a gas fire depends largely upon the degree in which the Kern idea is realized.

[NOTE.—Strictly speaking there is no actual contact between a "living" flame and a foreign body upon which it appears to impinge. There is always a layer of dead gaseous matter interposing, which prevents the actual temperature of the flame from passing into the foreign body; thus causing great loss. Hence it must be understood that in speaking of a "solid" flame, and the effect of utilizing it with flame "contact," the terms are used in their popular sense.]

11. It is possible to increase the primary aeration of a bunsen flame to the total quantity of the air of combustion (about 5 volumes to 1 volume of 14 candle gas) if the velocity of the mixture in the bunsen tube is greater than that of propagation backwards of the flame. This is the reason for increasing the pressure of gas or air in high pressure lighting or heating systems; the pressure being transformed into velocity.
12. The form of the mixing tube is better if made near the gas jet doubly conical, on the Venturi principle, whereby the air is drawn in parallel to the flow of the gas, which is an expanding jet. By this device the skin friction of the mixture against the inside of the tube is diminished.

Domestic Warming by Gas.

THE warming of living and bedrooms in private houses by gas is the most important of its applications to heating purposes (apart from cooking) commonly employed by private consumers; and the "gas fire," either self-contained or made up in a coal fire grate converted to the purpose, is the type of apparatus almost exclusively used by the British public as a substitute for a coal fire.

Briefly stated, the gas "fire" means an arrangement of bunsen burner and some refractory element, whereby as much as possible of the total heat of combustion of the gas shall be realized as radiant heat, like that of a coal fire, and the products of combustion shall be removed from the apartment; also like a coal fire. In other words, the gas fire is as close an imitation as possible of the good points of a coal fire, with avoidance of its drawbacks and defects.

The modern gas fire therefore lends itself to particular examination and criticism on several independent lines. We can consider it broadly, as it appeals to the public, in the capacity of a substitute for the usual coal fire; and we should then proceed to investigate it in detail, with a view to judging how far any particular example fulfils the proper requirements of such an appliance as would be approved by a discriminating user.

In the first place, then, the substitution of gas for coal as the fuel of the domestic hearth must proceed along the lines of established custom. In England this means the open coal fire, which is not only a national fetish, so to speak, but is actually in possession of the situation. There is a fireplace in every room of a British house; and the fact has to be reckoned with. Possibly a cheaper method of warming the house, or at least of "keeping the chill off" could be suggested in the shape of warm water pipes; but the change would be expensive to carry out, and few tenants of rented houses will entertain a general proposition of the kind.

The conscientious believer in the superior advantages of gas over coal fires will arm himself with a sufficiency of practical reasons for his faith; and after he has gained his point he will see to it that there is no failure of justification.

The modern vogue of gas fires is as much due to their difference from as their similarity to coal fires. The coal fire suits the Englishman's tastes, and also the uncertain but rarely severe English winter climate. Suffice it to point out that a coal fire can still be enjoyed in the most-used room of the house; for it is not claimed at present that the gas fire is cheaper than coal or coke for long-continued use. One such fire in a house may be kept on this account, and for the sake of old associations; but in towns where gas can be had at any price from 3s. per 1,000 cubic feet downwards, it is cheaper than coal for any fire burnt for six hours a day, or less.

The other advantages of a good modern gas fire over even the best coal fire are numerous and considerable. The following considerations weigh with householders, and should therefore be borne in mind by gas fitters :—

1. A good modern gas fire, whether self-contained or made up in a converted fire-grate, is quite as effective in warming a room as a coal fire, and does it more quickly.
2. It does it also in precisely the same way, namely, by radiant heat; and ventilates the room just as well, by the same chimney.
3. It arrives at its greatest effective power within a quarter of an hour after lighting up.
4. It will keep in for any length of time without attention. This quality alone renders it invaluable for the sick room.
5. It is always ready, and makes no dirt or extra work.
6. It is the only practical means of curing the smoke nuisance of towns.

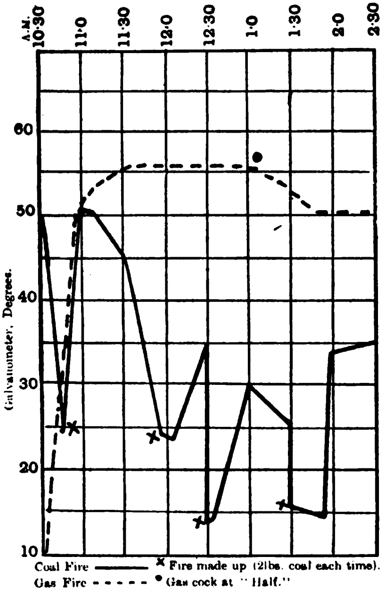


Fig. 38. Radiant Heat Effects of Coal and Gas Fires.

A comparison between the regular effect of a gas fire and the irregularity of a coal fire is exhibited by the accompanying diagram. (Fig. 38.)

The experiment was carried out by the author personally in two precisely similar ground floor rooms, each provided with a 14-inch "canopy" pattern fire-grate. The chimney draught was excellent in each case; adequate, without being excessive. One grate was fitted with a gas fire, of a well-known description, the back being filled in with a fire-clay block, and tubular radiants in front. The full consumption averaged 42 cubic feet of gas per hour, reduced to 25 cubic feet per hour by turning the duplex cock to "half." Flames regulated by quadrant-cock on supply, so as to just show above top of "fuel." Gas pressure about 23-tenths. The gas flames were by no means "keen"; and the combustion was silent.

On the previous day a test had been carried out upon the twin fire-grate in the next room, burning coal. The outside air temperature on both days during the hours of the test was about 45°, and therefore it was not desired to push the fire. The atmospheric conditions as to temperature, wind, and moisture were pretty much what may be regarded as typical of most of the days of moist English winters. The results of both observations are shown by the chart.

The chart needs little explanation. The readings were taken half-hourly. The solid line is the coal fire trace, which started with the fire burning brightly, it having been lit about two and a half hours. If the instrument had then been put down in front of the fireplace to wait for the radiant effect, the indication of the radiant action would probably have started half-an-hour later, and risen to the maximum by a very hollow curve. This slowness of a coal fire is well known; and it is also much affected by variations of skill in the laying, etc.

During these observations the rooms were occupied and used in the ordinary way; with windows partly open, and doors continually being left ajar by inmates entering and leaving. Yet the temperature in both was maintained steadily at 58°—60° on the wall 4ft. 6in. from the floor. The air in the gas-fire room was kept at about 71 per cent. of moisture saturation point. In short, there was nothing to choose between the two methods of heating, from any point of view.

It has been mentioned that a modern gas fire does its work entirely by radiation of heat, like a coal fire. This remark requires explanation.

It has been stated that the total heating effect, or fuel value, of a cubic foot of gas is the same, irrespective of the manner of its burning. Different methods of burning, however, do affect the relative proportions of the three ways in which the aforesaid total heating effect is produced.

All artificial sources of heat, from gas flames and coal fires to hot-water bottles, give off their heat by (*a*) radiation; (*b*) convection; (*c*) conduction.

(*a*) Radiant heat is the kind of warmth produced by the sun's rays, which do not raise the temperature of the air through which they pass. It is a form of energy which is confined to solid bodies—that is, it must originate with a solid substance, and can only act upon a solid. Hence, a sufficiently hot solid body will heat by radiation, within its effective range, another body directly exposed to the rays—as, for example, the persons and the furniture in a room with an open fire—while the intervening air will be unaffected by the rays. This method of heating is esteemed the healthiest as it certainly is the pleasantest; because it produces its comfortable effect immediately, and without rendering the air stuffy or dry. For occupied rooms, however, this immediate effect, which varies greatly with the distance from the fire, requires to be supplemented and modified by a certain amount of indirect warming of the air by its contact with the warmed furniture. Still, the warmth is essentially that of radiation, so long as the atmosphere acquires such heat as it reveals by the thermometer *from* the furniture and other solids in the room. This temperature is not usually, in the United Kingdom, required to exceed 62° Fahr. for living rooms occupied for sedentary employments. For sick rooms and nurseries 60° Fahr. is preferable; and 56° Fahr. is warm enough for the sleeping rooms of healthy people. Interiors where active labour is being carried on do not require to be heated artificially above 54° Fahr. Usually, the great defect in connection with the radiant heating of rooms by coal fires is the cold draughts of air induced by the chimney; which grow keener as the fire is made stronger.

(*b*) Convected heat is that effect of an artificial source of heat which concerns the atmosphere. It is the heat which is carried upwards, in the sensible form of hot air, from hot water pipes, the surface of closed stoves, and in the combustion production of all flames and fires. Where the fires are smoky or give off sulphurous fumes like those of coal or coke, this part of their heat is sacrificed by the chimney. Convected heat from charcoal braziers, oil lamps, and open gas flames is carried up partly by the heated air passing over the burning fuel; but mainly by the products of combustion, which eventually part with their heat to the atmosphere. From the point of view of room heating the distinguishing feature of this method of warming consists in the fact of the air (whether mixed with products of combustion or not) giving heat *to* the contents of the room.

This condition may entail a considerable super-elevation of the air temperature above that of the body; which means its corresponding expansion and diminution of the oxygen content in a given bulk, and also an increased drying effect. Consequently, stove heat imposes upon animals more rapid breathing, and excessive skin action. The discomfort is minimised in the case of large public buildings, etc., where there is much circulation of traffic, and the process of heating is so regular and continuous that the super-elevation of the interior atmosphere can be reduced to an ascertained minimum. Yet, the air of such places never feels fresh, and the problem of providing adequate ventilation without lowering the temperature in cold weather has proved insoluble in numerous instances.

The objection, therefore, to warming living rooms by any convection system applies with equal force to the character of the heating effects, whether odourless combustion products happen to be mixed with the heated air or not. The peculiar quality of such a method of conveying heat is independent of the subsidiary question of whether the hot air does or does not contain an insignificant addition of pure CO_2 gas. It is, however, the only available (and the cheapest) way of "taking the chill off" the air of shops, kinema halls, etc., which have no flue; and this can be quite well performed by gas air-warming apparatus working *without flame contact.*

(*c*) The Conduction of heat by bodies in contact with a source of heat does not enter into the practical warming of rooms; but is chiefly of importance in connection with the construction of burners and fireplaces. The parts of apparatus in contact with flame or fire are required to be made of material which is a bad conductor of heat, in order to prevent loss of heat by conduction.

If the total heat produced by burning gas with a luminous or bunsen flame is represented by the figure 100, then the relative proportions of radiant, convected and conducted heat in this total will be :—

Radiant	15 to 18.
Convected	75.
Conducted	7 to 10.

These are merely approximate figures; but they are exact enough to exhibit the weakness of town's gas as a direct source of radiant heat. Evidently, if only this part of the total heating power of the gas flame is to be utilised, there will be enormous waste; and since gas is a high-priced fuel, this wastefulness would put it out of the running with a fuel such as coal, which is not only cheaper, but has a radiant heat efficiency of from 19 to 42 per cent. That is, when burnt in a good modern fireplace, 42 per cent. of the total heating power of the coal is realized as radiated heat, when the fire is burning clear and at its best; otherwise the radiant efficiency is less.

On the other hand, where the circumstances permit of the simultaneous utilization of the convected heat also, gas shows an advantage over coal; because all the convected heat of the latter fuel, as burnt in the domestic fire-grate, must go away up the chimney with the smoke. Therefore its 42 per cent. maximum radiant heat efficiency (figure determined for the Smoke Abatement Committee by the late D. Kinnear Clark) must be regarded as its total fuel value, when burnt in a domestic fireplace.

Flat-flame and other gas lighting burners have long been applied in various forms of " stoves " as sources of heat, without flues. In such cases, the heating efficiency of the apparatus and the fuel is 100 per cent., since there is no waste. As will be understood from the figures given above, the greater portion of this heating effect will be due to convection, and is therefore not upon all fours with the warmth of a coal fire. The two cases are not comparable, even though a wall thermometer might show the same temperature with each, for the reason already stated.

In order to compete on the same basis with coal fires, gas must be brought up to something approaching equality of heat radiating power.

Further consideration of the phenomena of radiant heat teaches that since it only proceeds from a solid body, and a luminous flame of gas only exhibits the appearance of solidity in the white or luminous part, the problem of making a gas-imitation of a coal fire is really a question of applying as much of its total heat as possible to render some foreign solid body hot enough to become in its turn an efficient heat radiating agent. We shall see that by following certain methods this result can be achieved, and the proportion of the total heat of gas rendered effective in the radiant form increased to 50 or 55 per cent.

The practical problem of the gas "fire" is first to produce a bunsen flame of high temperature, and then to convert this flame temperature into radiant energy taking effect, as heat, from the surface of a solid body. Essentially the problems of converting as much as possible of the total heat of the burning gas into light by means of the Welsbach mantle, and into radiant warmth by means of the hot body constituting the gas "fire" are identical. The power employed—gas—is the same; and it is employed in the same way in each case, namely, as a high temperature bunsen flame.

The progressive development of the gas fire has consisted in shedding one stupid blunder after another, and eventually in settling upon a practice which is after all nothing more than simple observance of natural laws quite well known. As usual, however, the men who started out to make gas fires did not know the laws in question; and those who did know them never thought of helping to make gas fires.

We shall perhaps better understand the nature of the modern improvements which have raised the radiant heat efficiency of the gas fire from the low figure appertaining to naked flames to its present maximum of 50 to 55 per cent.—thus bettering the efficiency of the coal fire—by following the actual course of this development.

It has, of course, long been known that a bunsen flame applied to heat pieces of any refractory substance, heaped in a fire-grate, would make an imitation of a coal or coke fire; but even when some attention was given to the manufacture of apparatus of the kind upon commercial lines, no attempt was made to realize the conditions of efficient performance.

In this regard the science of Germany proved as blind as British rule-o'-thumb. The accompanying figure (Fig. 39) taken a few years since from an official

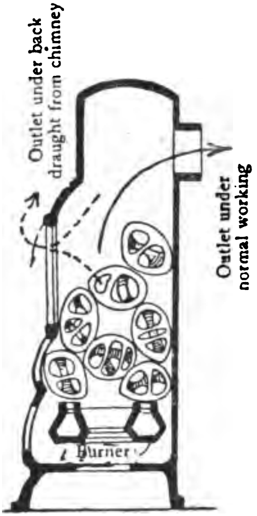


Fig. 39. DEFECTIVE GERMAN GAS FIRE.

German notification displays all the defects possible to embody in an apparatus of the kind. All such trade articles of the period were alike. The bunsen flames were not adjustable for gas and air; nor removable for cleaning. The flames found their way among the pieces of fire-clay, anyhow. One row of burners was placed behind another, regardless of the proper purpose to be served. There was no care to give access of secondary air, to complete the combustion of the gas within a reasonable distance from the outlet of the burner. Consequently, there were flames flaring right above the fire-brick "fuel" altogether, wasting their heat beyond the possibility of radiant action. Pieces of the solid material rested on the burners, choking the flames. No single jet of flame could burn itself out properly and completely. Result—an evilly smelling affair, burning gas at the rate of 75 or 80 cubic feet per hour, producing a hot heap of "fuels," indeed; but with a radiation efficiency of not more than 22 or 23 per cent., and a liberal discharge of combustion products into the atmosphere of the room, unless the chimney draught happened to be excessive.

In the hope of improving the heating effect of such apparatus many patterns of self-contained gas fires sold under fancy names were constructed as a sort of hybrid between an open fireplace operating by radiation, and a closed stove warming air in channels.

This cross was a failure. The heat supposed to be economically applied in warming the air was merely borrowed from the flames. The only way of truly recovering the heat of convection, once entered into flues leading to a chimney, is to expose the flue pipe in the room; as is done with the closed stoves used in cold climates. This, of course, is practically impossible in ordinary British practice; and no half-measures in this direction are of any avail.

The actual progress of improvement in British gas fires took the course of (*a*) concentrating the rambling gas flames into a front row of separate jets, ordinarily rated to consume 3 cubic feet of gas an hour, at standard pressure of 20-tenths. These jets are spaced far enough apart to avoid interfering with one another; and their length can be controlled by the proper adjustment of the gas and air of the bunsen. (*b*) The solid substance necessary for radiation was by degrees modelled upon the form of the Welsbach incandescent lighting mantle, and so disposed as to surround and just touch the outer edge of the flame without interfering with the combustion; (*c*) the fireclay backing of the radiants was brought forward so as to reflect back upon them the heat that would otherwise be lost; and the heavy metallic front bars were dispensed with. In this way an effective heat radiating front is formed, in which the conversion of the heat of combustion of the gas is carried to the not unsatisfactory figure of 50-55 per cent. (Fig. 40.)

How this rate of efficiency is to be further improved upon is not at present perceivable, under the conditions imposed by the usual fireplace and chimney. There must be some unavoidable waste of heat by excessive chimney draught, so long as flues constructed for coal fires, and therefore large enough to allow for sweeping, are converted to the much smaller ventilation requirements of gas fires quite powerful enough for the rooms.

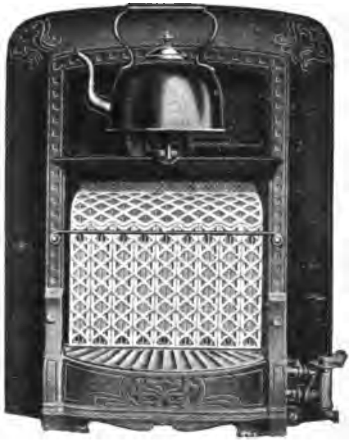


Fig. 40. Improved Gas Fire.
(" Sola "), 1913.

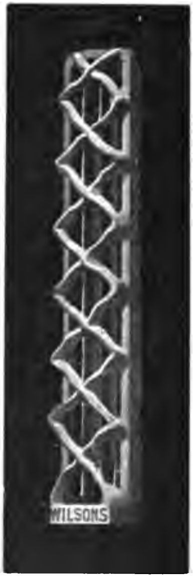


Fig. 40b. Radiant.

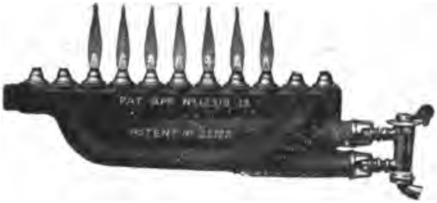


Fig. 40a. Burner.

The extent of the loss of heating power entailed by the radiation-heating only of existing buidings is seldom considered. Taking the case of any dwelling house with the usual fireplaces for warming by means of coal fires, experience proves that equal warmth can be obtained by modern gas fires proportioned to the rooms as follows :—

Room Measuring (cubic feet.)	Gas fire consumption (cubic ft. per hour.)
1000	15
1500	30
2000	45*

*At first; reducible to 25 by "half" duplex cock.

Assume that the chimney draught, etc., changes the air of the room three times an hour, and that it is desired to maintain within it a mean air temperature of 60° Fahr. when the temperature outside is at 40° Fahrenheit.

Then the work to be done in the case of the middle-sized room, of 1,500 cubic feet capacity, which is a very usual "villa" size, is to raise 4,500 cubic feet of air 20° in temperature, per hour. The specific heat of air is 0·02 B.Th.U. per cubic foot.

Consequently the amount of heat necessary for the purpose is $4{,}500 \times 20 \times 0{\cdot}02 = 1{,}800$ B.Th.U. per hour. Adding, say, 25 per cent. for loss of heat by the window glass and walls, the total requirement works out to $1{,}800 + 450 = 2{,}250$ B.Th.U. per hour. The calorific power of the gas is 500 B.Th.U. per cubic foot. Assuming an efficiency of 50 per cent. of radiant heat, the hourly consumption of the gas fire necessary to warm the room to the required temperature would be $\frac{2250}{250} = 9$ cubic feet. In practice, as we have seen, it is upwards of three times as much; which excess is partly due to chimney action. This cannot be properly termed waste, however, a large part of it being deliberately sacrificed to pay for the favourite radiant form of heat, and for ventilating the room.

The Hygiene of the Gas Fire.

Of equal importance with the good radiation efficiency of a gas fire is its hygienic reputation; which depends upon the completeness of the flue action in removing every trace of the combustion products from the room. This latter is essential. However scientifically the bunsen flames and the radiating bodies may be proportioned and adjusted to one another, so as to avoid the smothering of the former by contact with the latter, there must of necessity be some contact, and the consequence of this is a certain escape of unburnt gas. Even were it otherwise, and only the gaseous and aqueous products of perfect combustion emanated from the burnt gas, it would be equally desirable to withdraw them from the room by the usual chimney flue, and to preserve the incidental ventilation.

Therefore, it is absolutely essential to success with the gas fire that the appliance itself and the flue action should be treated as of a piece, so that the radiant warmth and adequate chimney ventilation should always go together and be esteemed of equal importance.

In so far as the design and construction of the self-contained gas fire have to do with its ventilating efficiency, the points to be regarded are the gathering up of the combustion products of the flames underneath the overhanging hood or canopy; the prevention of any leakage from this part into the room; and the non-returnable discharge of the ventilation current by means of the chimney.

The first stage of this progress is carried out by forming and proportioning the canopy and flue outlet of the fire as illustrated herewith (Fig. 41).

Different makers hold slightly different views respecting the best relative proportions and forms of these necessary elements of gas fire design and construction; but all agree that when the fire is lighted the products of combustion should immediately find their way to and out of the provided flue, without any assistance from the natural pull of the chimney.

At the same time, this result is much helped if the door or window of the room is open at the time of lighting.

The action of the flue has not only to deal with the products of combustion, which have not much heat in them at first; but it must also promote a flow of air up the chimney. There is not much fear of any modern pattern of self-contained gas fire acting in this regard with such excess of energy—like that of a fierce coal fire—as to cause unpleasant draughts at the floor level.

The rising products of combustion, once fairly started on their way up the chimney, carry a far larger bulk of air with them, and so ventilate the room. Unless the lower edge of the canopy is brought down too low, the amount of the pull of the chimney will not materially affect the radiant efficiency of the fire.

The ventilating efficiency of a gas fire can be tested by holding a piece of glass just above the lower edge of the canopy. If any combustion products are escaping the glass will be dimmed by condensed moisture. When a fire is fixed in a room it is necessary to try for such escape all along the edge of the canopy; because a cross draught of air may cause an outward eddy on the leeward side.

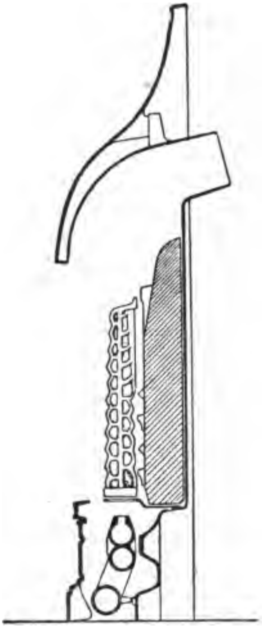


Fig. 41.

VERTICAL SECTION THROUGH CANOPY & FLUE OF A MODERN GAS FIRE.

(Giving radiant heat only, with perfect removal of combustion products, and efficient room ventilation.)

Mr. W. J. A. Butterfield finds that the diluted products issuing from the flue opening of a modern gas fire of the general design above described will always have a dew point somewhere between 77° and 116° Fahr. Seeing that the dew point of the air in the room will probably be about 54° Fahr., it will be easy to prove the presence of flue gas by observing if there is condensation on glass at a temperature of 75° Fahr. or over. The inward pull of the chimney draught can also be observed by the drawing in of the flame of a taper.

There must be no sharp turns or sudden restrictions of bore in the uptake flue. An extension of the flue opening of the fire by a piece of pipe into the chimney is not really necessary with a modern fire, which, as already observed, should be independent of the pull of a chimney. Where such a length of flue pipe is insisted upon by unintelligent regulations, fitters are apt to jam it in anyhow, if the chimney (as often happens) has an awkward angle just over the fireplace. No talc valves or other perishable fittings should be enclosed in the chimney.

If there is a decided down draught, this must be attacked from the chimney top, not at the bottom. "Browning's cowl" is an excellent remedy. It consists of a short length of 4in. flue pipe dropped into the chimney pot, with a flange to rest upon, and the top end covered with a conical cap. (The same device in a smaller size can be recommended for geyser flues, where troublesome.) Wind cannot blow down the flue, and the partial restriction of the cross section of the chimney tends to fill the lower portion with warm air which eventually finds its outlet without eddies.

Gas fires are usually set in fireplaces from which the front bars are removed, if possible, and the breast opening closed in with a sheet of iron or "emdeca," fastened up with set-screws. An opening is cut to take the flue of the fire. Before fixing, the chimney must be thoroughly swept. The gas connection is preferably made by means of a length of brass pipe, with a quadrant cock on the iron barrel supply. If the gas pressure is over 30-tenths a pressure governor should be fixed to reduce it to 20-tenths.

The variety of gas fire which is made in an ordinary fire-grate has had an arduous struggle for existence; partly perhaps because there is less to sell. The tradition of its inferiority as a heat-producer has been spread abroad; but inasmuch as all gas fires now depend upon radiation efficiency only, there is no valid reason why an arrangement built up in a suitable fixed grate should be less efficient in this respect than a self-contained apparatus standing in the fireplace.

If this possibility is granted—and the evidence given on p. 149 should dispel all reasonable doubt on the question—there is much more to be said for the fire-in-the-grate principle. The change from coal to gas does not alter the style of decoration of the room, and the same efficiency of ventilation is preserved without excess. The absence of floor draughts in a room so fitted is remarkable.

Usually, the fireplace is wide enough for a duplex fitting; which is to be recommended. The same points as to pressure, gas connection, a clean chimney and so forth of course apply to all gas fires. The "canopy" style of fire-grate lends itself most easily to successful conversion to gas, the back of the grate being filled up solid and the bunsen tubes lined along the front, with sufficient clearance for the flames not to be broken before entering the columnar radiants. The same precaution is necessary with sloping radiants, which are adopted for imitating the "hearth" or "well" type of coal fire. All the flames should be of equal length.

There are many patterns of ready-made gas fires for fitting into existing fireplaces. In all these examples the free-burning flame must be embodied, and the production of a reasonably good radiant effect should be a *sine quâ non.*

In general the plainer and simpler the casing of gas fires the better. There should be as little invitation for the accumulation of dust as possible. All gas burners should be easily accessible and removable for the annual cleaning, which should be undertaken without charge by the gas company. Self-contained gas fires in bedrooms or dressing rooms should have a boiling burner attached, the flames of which should be carefully adjusted to prevent smell.

No gas fire should ever be left in a house without full instructions as to the manner of lighting, and what to do in the event of back-firing.

Flueless Gas Warming Apparatus.

THERE are some patterns of gas heating apparatus in the market which combine an open radiant "fire" with an arrangement of convection tubes for the products of combustion, the latter having no flue connection. It must never be forgotten, however, that wherever a gas flame has thus come into contact with a foreign body more substantial than an illuminating mantle, products of interrupted combustion are formed which require a flue to remove them from an interior. However "keen" the bunsen flame, it always suffers partial smothering with cold contact. Hence the only flueless gas warming apparatus that should be allowed in a closed interior are such as employ luminous flames, or bunsen flames which do not make contact with the substance of the structure. Even so, the effect of the convected heat will be unpleasant unless the quantity of gas consumed is kept below that at which the volume of the combustion products would fail to be removed by the ordinary ventilation. It follows that for crowded interiors such warming apparatus is inadmissible unless ventilated.

The Home Office has instructed H.M. Inspectors of Factories and Workshops that flueless warming apparatus will not be permitted to be used under conditions likely to increase the CO_2 content of the enclosed air to more than 12 parts in 10,000.

The use of flueless gas heating appliances cannot be foregone for very many well ventilated situations otherwise destitute of means of warming; and no ill-effects are to be feared from such use, if a few elementary precautions are observed.

First, the apparatus must not permit of actual contact of the gas flames, however highly bunsenized, with any part of its structure. The products of combustion will therefore be of the same nature as those of gas burnt for illumination; namely, pure carbonic acid gas and water vapour; with a minute trace of sulphurous acid, which is a disinfectant.

No harm has ever been proved to have been caused to a living being by any likely or even possible quantity of the above combustion products, discharged into the air of an interior warmed or lighted by the free-burning flames of gas.

For the present purpose it is sufficient to observe that where the circulation of the air of an interior is reasonably active—sufficiently so to prevent any odour of "closeness," or distinct smell of people, clothes, eatables, and so forth—the chill may very properly be taken off the air in cold weather by any flueless gas warming apparatus with free-burning flames. Large interiors in occasional use, such as churches, assembly halls, theatres, and other interiors densely occupied for a time by people sitting still can be cheaply warmed *beforehand* by burning gas in tubular "gas steam radiators," consuming at the maximum rate of 4 cubic feet per hour per 1,000 cubic feet of cubic capacity of the interior. This is an average rule which may require to be altered in some situations. If the gas is turned out when the doors are opened, there will be no contamination of the remaining atmosphere. The air temperature should not be raised finally above 55° Fahr.

Corridors, landings, and stairways can be similarly treated; but without extinguishing the gas.

"Condensing" bunsen-flame tube stoves with "fire" fronts are to be condemned unless adequately ventilated.

Shops, post offices, waiting rooms, etc., can be made comfortable enough with a very moderate degree of constant warming. On no account should this or any other method of convection heating be overdone.

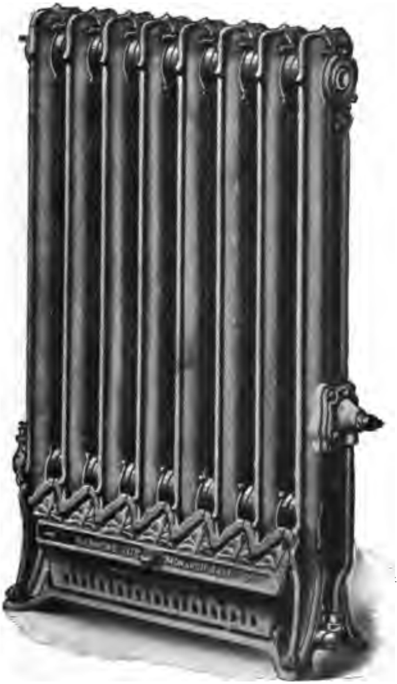
Quite small "bar" stoves, with water heaters attached, are extremely useful for inns, refreshment rooms, etc.

The great convenience of this means of heating interiors devoid of chimneys warrants the taking of pains to render it available by the public in an inoffensive manner. Inasmuch as the heating efficiency of any variety of gas flame burning freely in the air of an enclosed space is 100 per cent., it is immaterial what pattern of apparatus is chosen for this purpose, so far as the warming effect is concerned. Care should be taken to have sufficient power to really raise and maintain the temperature of the air until the interior surface of the glazed, painted, or varnished woodwork or metal is warmed above the dew point; or there will be condensation of moisture and consequent "clamminess" of feeling. This latter effect of burning gas in an interior not thoroughly ventilated may consequently be due to burning too little gas, and not too much, as is frequently suspected. The best appliance for the purpose is the "gas steam radiator," which is self-adjusting for consumption, and if flame-contact is avoided is quite odourless.

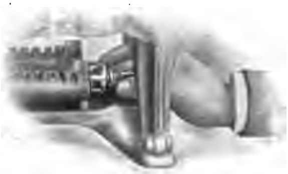
Where high-pressure gas is available in a factory or workshop, and is used to fire a boiler, the iron flue from the same can be led through the shop, with a fall all the way towards the outlet opening to a short chimney outside. This would prove a source of considerable warmth; but would, of course, require to be by-passed when not wanted. That is a defect of all combination systems for "killing two birds with one stone." The second bird is not always there; or is there at the wrong time.

The best arrangement for warming large factories and workshops, furniture and music warerooms, garages, danger places, etc. with gas is by circulating hot

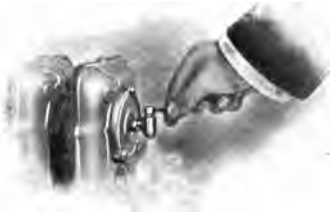
Fig. 42. A Gas Steam Radiator, showing the Parts requiring attention.



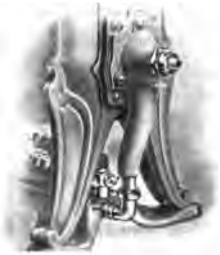
The Radiator.



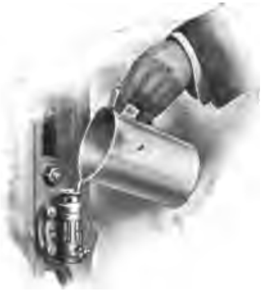
a. The Air and Gas Adjustment.



b. Blowing off Air.



c. The Gas Control Valve.



d. The Water Feed.

water in the usual style, heated from a boiler placed *outside* the enclosure. The gas consumption in this case will be about 25 per cent. higher than when the flame burns freely inside—that is, the system should have a working efficiency of about 75 per cent.

Air warming, to a moderate elevation of the temperature, can be advantageously combined with forced ventilation of crowded and hemmed-in interiors, such as law courts, banqueting halls, council chambers, etc., in which the lighting is done by means of air-extracting ceiling lamps. The fresh air can be driven in by gas-driven fans through inlets opening into the apartment at about 8ft. from the floor, passing over enamelled iron tubes of gas radiators of special design. Every problem of the kind must, of course, be solved with regard to the particular conditions.

Air is so easily and quickly warmed that in many cases where this is required to be done, for medical or trade purposes, gas can very often be successfully employed in substitution of solid fuel, by proceeding in agreement with the foregoing principles.

[Note.—It may be convenient to mention here that although the condensation of moisture from or in connection with the free burning of gas in interiors may dull the polish of bright metal it will not actually discolour or tarnish it. Only sulphuretted hydrogen (present in smoky and foggy air) will have this effect.]

Industrial Applications of Gas.

This branch of gas utilization practice means almost entirely furnace work; although it includes the generation of steam, and a variety of flame work such as blowpipe operations.

Although the latest of the trade applications of gas as fuel, the number of proved profitable and advantageous uses of gas coming into this category is too great to be described to good purpose in a book of this character; and fresh successes appear every time the subject crops up at professional gatherings, so that any catalogue would quickly pass out of date. It is therefore only worth while to review the guiding principles emerging from a brief survey of the main lines of this advance.

Although there were many workshops and trade uses of gas as fuel for which the industry is indebted to the late Thomas Fletcher and other pioneers, it was chiefly with the introduction of high pressure of the gas or the air required for intensified bunsen combustion, that the modern era of the industrial applications of town gas commenced. The name most prominently associated with this fresh departure is that of the late W. A. Onslow, of the Woolwich Arsenal, who proved by demonstration that coal gas at a gauge pressure of from 4 to 8 inches of mercury was quicker, more certain, and cheaper than either solid or producer gas fuel for the most important welding, tempering, and many other operations of the Arsenal. It is in the quality of *command of the work* that high pressure town's gas surpasses all other industrial fuels. This means that failure is practically impossible, so far as the heating is concerned; which is a more important consideration for manufacturers than any question of comparative cost of fuels.

Mr. Onslow was also convinced by his experience that high pressure gas, and air at ordinary atmospheric pressure is better than pressure air and low pressure gas, apart from the greater expense of the latter.

In regard to the machine for raising the gas pressure in the case of private installations Mr. Onslow offered the following advice in a lecture :—

" The apparatus should be as simple as possible, with as few parts to be deranged as it compatible with utility.

" Remember that when drawing gas from the main pressure there is a certain amount of responsibility on both sides. If certain districts, railway stations, or large works have to be provided with gas at 50 to 100 inches (water) pressure, this must be maintained without any fluctuations or differences of pressure—as from 20 to 60 inches—or temporary stoppages for oiling up. So at the outset—simplicity

" I have several instances where the plant has not been touched for four years, except to lubricate; so look well after lubrication.

" Don't have bits of tin, wire or anything about the pressure plant likely to become loose; but the workmanship should be good, strong, and serviceable. A little trouble and outlay at first saves much heart-burning afterwards.

"A plant when ready to start should be in such a state that no shutting down to do this or that is necessary.

"All pipes before starting should be tested under pressure, either of air or gas; if with air, allow double the proposed gas pressure. Allow the air or gas to be bottled up in the pipes after the machine is stopped. Note reduction of pressure due to leakage. If the pressure on the gauge is not reduced sensibly in five minutes, you can conclude the pipes are satisfactory; but never put a new plant to work without testing for leakages, and thoroughly make good defects.

"A machine for raising pressure, if powerful, will be sure to have all the gas it requires; so look out on the suction side of the compressor for shortage. Whatever else goes short of gas, it will not be the compressor. If the compressor is run off a meter, the connection should be the full size of the meter inlet, and the meter should be of the full rated size for the maximum consumption. A dry meter must be used. There must never be exhaust or *minus* pressure in the suction pipe.

"A simple rule for the size of the pressure gas pipes is that they should be half the capacity of the inlet or suction pipes.

"Reduce from the compression easily, by diminishing sockets; not suddenly.

"Make your screwed joints as for steam; wind a piece of flax or grummet round the thread, coat it with paint, and screw well home. The ideal joint is to have the ends of the pipe faced in a machine and both ends to hold together in the socket; the faced ends being painted beforehand. Ordinary gas tubing is good enough for pressures up to 100 inches."

For the special requirements of Arsenal work, comprising the shrinking-on of big gun rings, the tempering of large steel bars, etc., various gas pressures might be called for; and it was often cheaper and less laborious to take the gas to the job and build a temporary furnace round the part to be heated, than to carry the material to a fixed furnace. Mr. Onslow therefore devised a form of bunsen burner in which the whole of the air is carried forward with the gas and the degree of aeration is readily adjusted. (Fig. 43.)

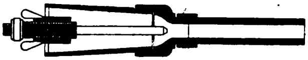


Fig. 43. ONSLOW'S HIGH-PRESSURE BUNSEN, FOR INDUSTRIAL MELTING AND TEMPERING FURNACES.

The burner is entered into the protecting casing tangentially to the firebrick inner surface; and the flame never plays directly upon the work. This has become the general rule in gas furnace working, except only where a direct blow-pipe action is desired. For welding in the open, a pair of bunsen burners directly opposite to one another, so that the flames come into contact, make quick work.

Professor W. A. Bone has since 1906 given much attention to the previously neglected phenomena of the influence of heated surfaces in promoting combustion; and in conjunction with Mr. M. Court has brought out a system of heating by gas and air burnt with pressure in contact with a granulated mass of refractory substance.

Apparently the same principle is embodied in the burner illustrated herewith, taken from a lecture by Dr. C. E. Lucke, delivered in October, 1913, before the Annual Meeting of the American Gas Institute. (Fig. 44.)

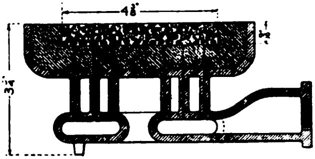


Fig. 44. Lucke's Surface Combustion Burner.

Here an explosive mixture of gas and air is driven under pressure through the small tubes into the granular mass of crushed fused silica, at a velocity sufficient to prevent back-lighting, while the small supply holes, one-sixteenth diameter, also cool the mixture below the point of ignition.

For low pressure gas the heating bunsen that burns the highest proportion of primary air, and consequently gives the highest flame temperature is the "A" type "Mecker" (Fig. 45). The form of the mixing tube favours the intake of air, and the top is closed with a nickel grid, ⅜ths of an inch deep, which prevents firing back at a gas pressure of 10-tenths and upwards. The single inner green cone of ordinary well-aerated plain tub bunsens here becomes subdivided into small bright blue cones, close down to the grid; and the rest of the flame is small and solid.

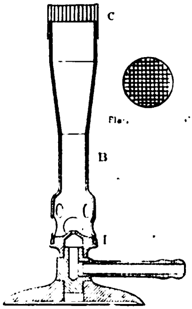


Fig. 45. The "Mecker" High-power, Low-pressure Burner.

[For detail information on this technic reference is directed to the papers of Mr. Onslow and Mr. E. W. Smith (Birmingham) in the Transactions of the Institution of Gas Engineers, 1912 and 1911; Messrs. E. W. Smith and C. M. Walter (Birmingham), 1913; and Mr. H. M. Thornton, Transactions of British Commercial Gas Association, 1913.]

Cookers.

THE business of the fitter in relation to the installing of the ordinary gas cooker is concerned with the proper fixing and adjustment of the apparatus chosen by the consumer. If at the same time he is able to offer a few useful hints as to the use and care of the different parts, it will help to create confidence in users without previous experience of gas cooking.

Gas cookers, whatever their size, must have a good supply of gas. Therefore, in the case of the larger sizes, the connection should if possible be direct from the meter, the pipe being no smaller anywhere than the inlet of the stove. Easy bends should be used where change of direction is necessary, not elbows or tees, because a large gas cooker in full work, possibly at the same time as the lights, fires and water heaters, is very sensitive to fluctuations of pressure.

As to pressure, the greatest uniformity possible should be aimed at, or the cooking may suffer. The greatest obstacle to the extended use of gas for domestic cooking is the carelessness and waste of servants, therefore anything the fitter can do to reduce the possible margin for extravagant or ignorant misuse of the apparatus should be done.

Where the gas pressure is found to exceed 25-tenths at the cooker connection, a pressure governor set to this maximum should be urgently recommended.

In a full-sized cooker, with oven and boiling top, including a griller, the great bulk of the gas consumption will take place on the top. This part of the apparatus should therefore receive particular attention in the interest of economy.

Full-sized cookers of the domestic type, of the usual British patterns, with an oven or roasting chamber measuring about 16 inches wide, 23 inches high and 16 inches deep in the clear, will have an average full gas consumption by the oven burners, at the pressure stated, of 30 cubic feet per hour. The griller will burn at least an equal quantity; and so will the largest boiling ring. There will also usually be a medium-sized burner consuming about 15 to 20 cubic feet per hour; and a " simmering " burner of 5 cubic feet hourly consumption.

When it is remembered that the oven gas is only required to be burnt at the full for a quarter of an hour for heating up the oven before the cooking is begun, and thereupon is lowered to half-flame length, which means two-thirds the consumption, or about 20 cubic feet of gas an hour or less during the cooking period; and also that in general the people using such stoves do not cook large joints in the oven more frequently than twice a week, with an occasional pie or small dish at other times, it will be evident that the importance of the oven as a gas consumer is not commensurate with its bulk and imposing appearance in the combination. Yet, curiously enough, it is to economizing the heat of the oven gas, or to recovering some of the escaping heat of the contents of the oven flue, that the ingenuity of would-be improvers of the ordinary cooker has been mainly directed.

Little attention of the same order has been bestowed upon the top burners, which are capable of consuming together fourfold the quantity of gas burnt in the oven; and are in far more frequent use.

Although the oven gas is invariably bunsenized, it will be gathered from what has been stated with regard to the nature of bunsen-flame action, that inasmuch as the flame does not come in contact with the metal of the oven it would not matter if the heat were produced by means of luminous or bunsen burners. For the sake of uniformity and convenience the bunsen style is preferred; the actual burners being simple and easy to remove for cleaning. In adjusting the oven flames, a "soft" flame rather than a "keen" one is the more suitable, as lending itself better to lowering. The mixing tubes should not be too large. (Fig. 46.)

The chief points for attention as regards the ventilation of the oven flames are the provision for the

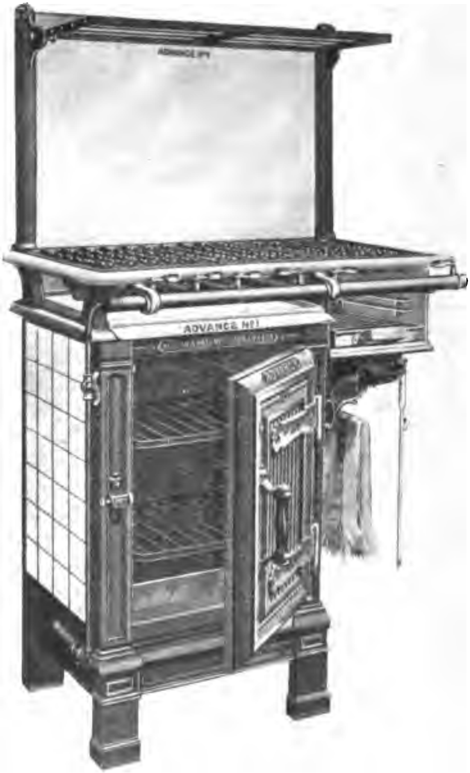


Fig. 46. A MODERN FAMILY GAS COOKER.

inlet of sufficient fresh air at the flame level; and the outlet for the combustion products and the hot air. It is better for the flames to take their primary air from outside the oven; and the secondary air should also enter through holes all along the length of the burner; and not at haphazard, through the loose fitting of the dripping pan. The oven flue outlet must be kept clean, and must be large enough to avoid smothering the flames while not giving too sharp a through draught (See, on this question, F. S. Larkin's paper on "Modern Gas Stove Construction," London and Southern District Junior Gas Association Transactions, 1913.)

It is not, as a rule, advisable for the fitter to meddle with the dimensions of the oven flue, but to see that it has no internal obstruction, and sufficient clearance. It is not expedient to connect the flue of an ordinary domestic gas oven with a chimney; but this is necessary with large restaurant, etc. ovens. The iron continuation flue should then be provided with a grease trap. No damper should be necessary: they are never properly used. The makers should send out stoves with proper vent proportions; and users should be instructed not to ever use the oven without the dripping pan in its proper place.

In the interest of safety the oven burner cock or cocks (it is preferable in large cookers for each side to have its own) should be as far as possible removed, and have unmistakably different handles from the top burner cocks.

The question of providing the cooker with a main cock has been much debated. It is thought to lead to explosions in the case of slot-meter installations easily accessible to children. For larger family stoves it may be desired, in order that the cooker may be put out of use at will.

The position of the gas cooker should be in the kitchen, not in the scullery, where it may be neglected. It should stand upon a stone, or sheet iron, in a good light, and be backed with "emdeca" on the wall. Family-size cookers should have a plate rack over.

Boiling burners have been the chief source of the offensive odour of smothered bunsen flames. This is due to bad design and wrong adjustment. Usually, also, too big burners are found in this position. There is an objection to providing cooker burners with gas and air adjusters or regulators, as these attachments get interfered with by servants either accidentally while cleaning, or intentionally to enlarge the flames. The adjustment to short, keen flames should be effected by the fitter hammering over the injector tip if necessary — carefully rounding out the jet orifice afterwards with a suitable broach. The primary air opening may be too big; in which case it should be reduced in size by inserting a metal sleeve in the tube.

The height of the jets should be such that *the green cone is not broken*, and when turned full on the combined flame never flares up beyond the edge of a pot or kettle of a size corresponding to the power of the burner. Some patterns of cooker have their boiling rings too close up to the grid to allow of this proper adjustment, and where this defect cannot be remedied by lowering the burners, the stove should be condemned, as it is certain to smell badly.

The burner holes of boiling rings should be big enough to admit a skewer for cleaning; and be spaced far enough apart to allow the secondary air to get round the separate flames when a pot is put over them. It is better for the jets to spread outward from the centre, and not to converge, which induces burning of the contents of cooking pots

See that all bunsen tubes, grids, oven shelves, and dripping pans are easily removable and replaceable without bungling or the use of force. The plugs of all cocks should be accessible for easing or tightening as required. The cocks should be out of the way of the pots on the boiling top.

The griller is one of the most difficult pieces of gas cooking apparatus. It should be of good size, which entails two independent burners; and the grid and dripping pan underneath should be adjustable for height. It is hardly possible to prevent the gas from smelling, since a large quantity has to be burnt in order to heat up the radiants quickly. Yet if the green cones of the jets are kept from breaking against the radiant the escape of offensively smelling gas will be reduced to the minimum, while the radiant will get hot quicker.

It has been suggested that the radiants should be of steel, as being less liable to distortion from repeated heating than cast-iron frets.

The open grid top of an ordinary cooker is seldom satisfactory. It commonly interferes with the free burning of the gas jets; and is open to the objection that the heat of the burners is only available right over the flame. For this reason, with the best-regulated burners only 50 per cent. of the heating power of the gas is utilized, the balance being dissipated in the air which circulates so freely round the vessels. A solid plate top, on which small vessels could be shifted about in relation to the heat beneath would probably remedy this, and may supersede the customary grid before long, as the gas cooker ceases to be regarded as an occasional aid to the coal kitchener; and is adopted in place of the latter for all the purposes served by the hot plate of the latter

Fitters responsible for the proper installation of cookers should never take for granted the proper condition or adjustment of any part of the apparatus. Be as careful as they may, the makers cannot provide against accidental derangements, nor anticipate the different qualities of gas their goods may be destined to deal with.

The common British type of domestic gas cooker, with its oven or roasting chamber, internally heated, below; and its boiling and grilling parts above has been developed to meet the demand for a semi-portable serviceable, strong, and durable apparatus calculated to prepare the family meals, and suitable for hiring out by the gas companies.

Consequently the competitive enterprise of the manufacturers has been in the main restricted to the lines of the accepted type; and departures from it were subject to the penalty of probable exclusion from the hiring lists. This influence has proved a serious obstacle to the experimental adaptation of gas cooking apparatus rather to the needs of the users, than to the four corners of a necessarily rigid hiring practice. Yet where a half-way house, in the form of hire-purchase, has been opened to promising novelties a good deal of elasticity has been manifested. At the present time there is a considerable and expanding market for this class of goods, independent of the gas undertakings.

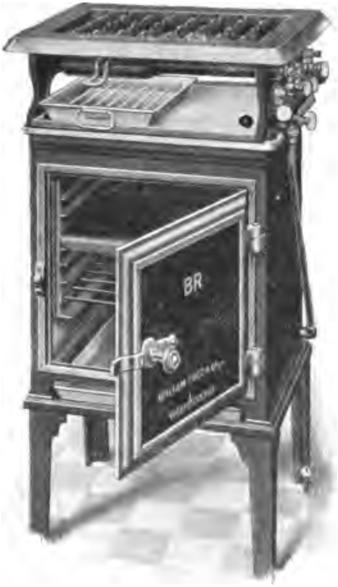
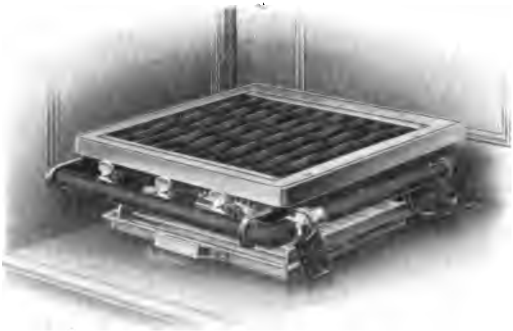


Fig. 47.
A Convenient Type of Gas Cooker for Small Needs.

The first development of this nature was in the direction of adapting gas to the cooking and serving requirements of large business houses, public institutions and the like, for which the reliability and handiness of the method proved its chief recommendation.

Of equal importance socially are the numerous small gas cooking appliances, designed to suit the purposes of persons doing their own housekeeping, nurses, night watchmen, etc., which can be put anywhere with the aid of a piece of metallic flexible tube. (Fig. 47.)

The same may be said of the devices for adapting gas as an accessory or alternative to the fixed coal range; which it frequently reduces to a state of complete abandonment for the greater part of the year. (Fig. 48.)



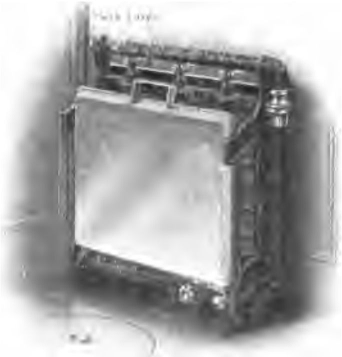


Fig. 48. A Gas Hot-Plate, as supplement to Coal Range.

An important share of the maintenance in good working order of all gas cooking apparatus consists in keeping it clean—not merely in the ordinary kitchen sense of black-leading and polishing the bright places (although this should not be neglected); but even more especially in regard to regularly removing grease from the interior of the oven, the grids, and shelves, and pans, etc. Users should be instructed to keep burner and primary air holes clear. It should be explained that owing to the heat being generated inside the oven the sides do not get overheated, so as to burn off the grease, as in the case of ovens fire-heated from outside.

It is always well for cookers to be overhauled by a competent maintenance hand once a year, and the griller parts, etc., renewed if necessary.

In all cooker-hiring departments the cleansing and restoring of cookers returned from hire is a serious business, but the procedure is outside the scope of this book.

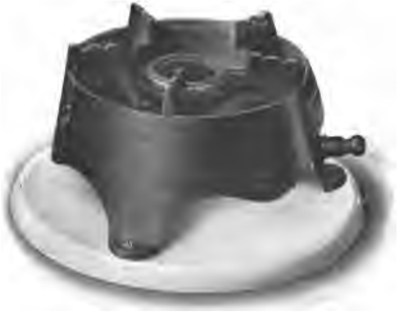


Fig. 49. A Good Type of Gas Boiling Ring.

A good type of Boiling Ring, with skirting to prevent draught blowing across the burner. Strongly made of cast-iron throughout. Mounted on circular porcelain-enamelled cast-iron base. Fitted with governor and connection for flexible tube.

It is remarkable how much cooking, by the aid of a sheet of iron, French fireclay ware, a frying-pan, or a " Boilerette " can be accomplished with such a simple burner as the above. Of course, there are cheaper patterns; but it should be a point with fitters and sale room attendants to advise users to choose the better article at a reasonable price. The public will always find the cheapest lines unaided; but need instruction to appreciate money's worth. This is particularly true of gas apparatus, the cost of which sinks into insignificance beside the value of the gas consumed during its lifetime.

In the case of a boiling ring, costing in any case from a few shillings down to a few pence, the gas consumption will not be affected by the design or construction of the ring; but a saving of ten per cent. of the heat developed may be secured by the use of the best type of ring, properly adjusted for gas and air. It follows from this consideration that the small additional first cost of the better article will be recovered over and over again before the apparatus is worn out.

Hot Water.

THE question of water heating, for washing-up and domestic purposes in general, including baths, has from the beginning waited on the progress of gas cooking. It was realized that the undoubted convenience and other incidental advantages of the gas cooker were heavily handicapped by the want of an equally convenient and adequate water heating accessory device. So long as this want remained unsatisfied the gas cooker could only rank as a supplement to the kitchen range, with its circulating boiler.

The early invention of the " geyser " type of water heater, although an excellent expedient for providing a warm bath in the absence of a circulating system, was for long limited to this particular use. There is no storage of the heated water, which takes up the heat of the burning gas instantaneously; and in the "Califont" form of the appliance flows wherever required, on the opening of a tap. The gas valve is controlled by the water pressure in such a way that opening the water tap turns on the gas, which ignites from a pilot flame. Luminous flames are used to avoid the risk of lighting-back of the large quantity of gas required to be burnt. The efficiency of this apparatus is very high, not only because the products of combustion of the gas are caused to part with almost the whole of their heat of convection to the adjacent water; but also because there is no loss of heat during storage. The temperature of the water can also be varied by drawing it off slowly or quickly; so that hot sink water can be had in a moment, or a bath filled in 15 to 20 minutes.

The use of the geyser type of water heaters is to raise the temperature of the water by about 50° Fahr., that is, from the temperature of the cold supply, to that of a warm bath, which is from 100° to 105° Fahr. The usual household size of this appliance will accomplish this purpose at the rate of about 2 gallons of water per minute, with a consumption for the same period of between 2½ and 3 cubic feet of gas.

Because the weight of 2 gallons of water is 20lbs. To raise 20lbs. of water through 50° of temperature requires 20 × 50 = 1,000 B.Th.U. The average effective fuel value of common gas is 500 B.Th.U. per cubic foot. Therefore, at 100 per cent. efficiency of the apparatus the consumption of gas for the purpose would be $\frac{1000}{500} = 2$ cubic feet. It must necessarily be more than this, according to the average efficiency of the apparatus, which may be taken at about 80 per cent. Say, 2½ cubic feet. At this rate, the consumption of gas, by geyser, to give a warm bath of 30 gallons, in 15 minutes, will average 45 cubic feet.

A good gas and water supply at the maximum demand, and a safe flue for conveying the flue gases away, either into the outer air, or, if this is difficult, into a roof space, are essential to the success of geysers.

The greatest impetus to the popularity of gas water heating on the full domestic scale was given by the successful introduction of "circulators," or circulating water heaters working in connection with or in substitution for the kitchen range boiler; thus utilizing the same pipe system and occupying little space in the kitchen itself. (Fig. 50.)

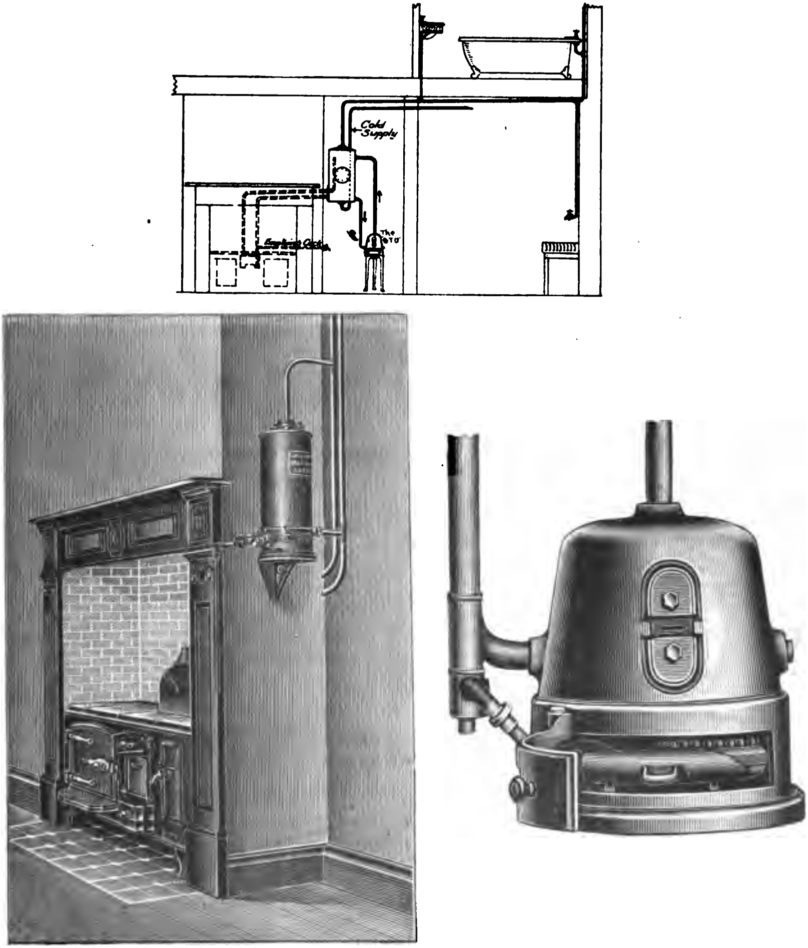


Fig. 50. Types of Hot Water Circulators, showing manner of Connections with existing H. & C. Water Piping.

The importance of this domestic use of gas to the suppliers may be appreciated from the observation that in an ordinary household the consumption of gas for water heating usually exceeds that for all other purposes combined.

Whatever form of apparatus is employed to produce the heat, the action of a circulating system of hot water supply for household purposes is the same. The cold feed is led to the lowest point of the system, where the heating apparatus is situated. This is commonly called the "boiler," but the word is a misnomer, inasmuch as the water ought never to boil. From here arises, keeping always in an upward direction, what is called the "flow" pipe, of which the total vertical height attained must be a safe margin above that of the cold feed cistern.

Somewhere in the length of the pipe system, preferably close over the boiler (of which it may or may not structurally form part) is a reservoir for the warmed water; which is drawn off from the top of the reservoir, whence arises a prolongation of the "flow" pipe called also the "expansion pipe." All the draw-off taps are on this pipe, in what is called the "cylinder" or "single pipe" system. In the "tank" system the reservoir is higher up from the boiler, and the draw-offs are often situated on the flow pipe between the tank and the boiler. It is often cheaper, where a reasonably efficient "tank" system already exists, to add a gas-heated "cylinder" system to it, instead of altering the old piping. (Fig. 51.)

A very economical combination is a coke-burning boiler, which can be interposed in any circulating system and is useful for consuming kitchen rubbish.

Certain considerations affect the satisfactory working of a circulating warm water system, which should be gone into before attempting to apply gas heat to an existing example.

In the first place it is necessary to inquire whether the existing arrangement is fairly efficient, so that a full bath of the proper temperature can be had within a reasonable time after the fire has been lighted. If not, the cause should be ascertained; because gas will not work a miracle by turning a bad system into a good one, and will only get discredited on account of excessive cost.

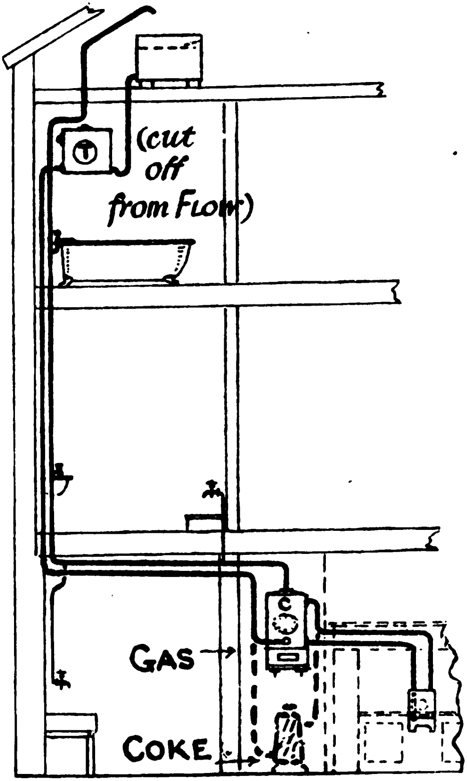


Fig. 51. Diagram of Converted "Tank" H.W. System; with interposed Cylinder and Gas (or Coke) Boiler.
(Taken from the Bulletin of The British Commercial Gas Association; with additions.)

If the system once worked better than it actually does, probably the boiler and the adjoining pipes are furred up and must be cleared.

If it has always been sluggish, the pipes may be too small, or improperly graded, or there are too many sharp elbows. Trace out and make a rough diagram of the piping.

If cool water follows quickly after the hot there is a short circuit of the feed somewhere, or the hot tank is not fed and drawn from the top, as it should be.

The motive power in every case is the greater weight of the cold feed or the "return" water, compared with the hot "flow" water. Therefore, in the circulatory system, it is the "return" water which pushes the "flow" up, so long as the heating is going on. When a draw-off tap is opened the force of gravity comes into operation, circulation is suspended, and the nearest water flows out. The object of the planning of the whole system is to ensure that this shall always be the hottest water; hence all draw-offs must be connected with the top of the hot water tank, or the expansion pipe.

With any good circulatory system a full-sized hot bath (30 galls. at 100° Fahr.) should be obtainable for a gas consumption at the rate of 1½ cubic feet per gallon, in 30 minutes from lighting up. Of course, ordinarily, when the system is in constant use and the stored water not stone-cold, a bath can be had in less time. There is no object in too quick heating, which means a heavy consumption. A happy mean between too quick and too slow operation is the best, which means for domestic single-bath sizes a maximum consumption of 80 cubic feet per hour.

In choosing a gas-heated water heating arrangement, other points than quick or even economical heating have to be considered. First of these is the question of effective gas control, with which is bound up the necessity of guarding against furring up of the boiler, and the pipes, in a hard-water locality.

For the latter reason, small coils, and circulators with narrow and inaccessible internal water spaces are quite unsuited to localities with hard water supply.

In any case, the water in a gas bath and sink-supplying system should never be permitted to get above 150° Fahr., at which the deposition of "fur" is not likely to become troublesome. Water ought never to boil in a circulatory system; although this not infrequently happens with coal range boilers. It is then that furring occurs, perhaps for a considerable distance in the piping.

For actually boiling water, a kettle or "gas boiler" is necessary; and the consumption of gas for this purpose will be about 6 cubic feet per gallon.

An instructive paper on Hot Water Supply, with special reference to two important points, namely :—

1. Comparison of efficiency of cylinder and tank systems of storage and piping, and
2. Comparison of actual cost and time of obtaining a hot bath from a range boiler and a gas boiler respectively;

was read before the Junior Institute of Engineers on February 28, 1913, by Mr. T. F. C. Potterton, and is published in the "Transactions" for the year.

The test apparatus in the first case was arranged in the following manner; and the diagram will also serve to illustrate the differences between the Cylinder and Tank systems. (Fig. 52.)

The cylinder storage is close down upon the boiler, and as the latter apparatus is at the bottom of the house while the cold water supply cistern is at the top, all the pressure due to the head of water (which it is customary, in order to be on the safe side, to take at ½lb. per square inch for every foot of vertical head) comes upon both pieces of apparatus. Boilers and cylinders should therefore be tested to 100lbs. per square inch hydraulic pressure.

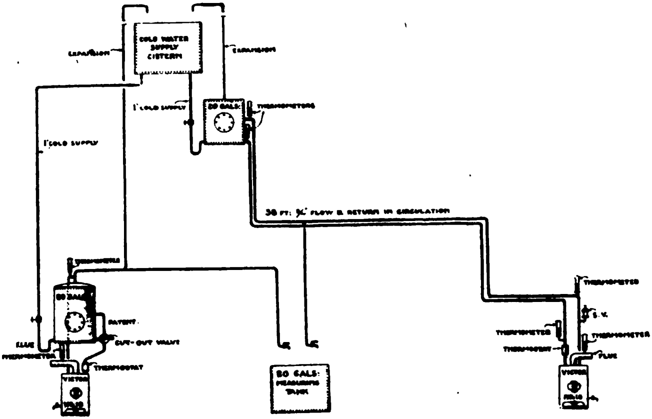


Fig. 52. General View of "Tank" and "Cylinder" Systems, arranged side by side for comparison; (from Potterton).

No such strain can be borne by the usual builders' grade of quadrangular tanks; which is one reason why in practice the "tank system" is invariably found installed in cheaply finished houses; the tank being as nearly as possible at the same level as the cold water supply tank. Thus the pressure due to head is avoided.

It is obvious from the diagram that as the draw-offs are on the expansion pipe above the hot water storage and the cold supply is fed into the base of it, any hot water in the cylinder must flow out first, without any admixture of cold. On the other hand, in the tank system with the draw-offs below the hot storage, a short circuit in the tank between the cold supply and the inlet of the flow pipe (the direction of flow in which is *reversed* between the tank and the draw-off when the latter is opened) must mix up the hot and cold water.

In the test a given quantity of gas burnt yielded with the cylinder system 20 gallons of water at 108° Fahr., and with the tank system the same quantity of water at 87° Fahr.

The diagram also illustrates the advantage offered by the cylinder system of cutting out part of the storage capacity when a quick supply of hot sink or lavatory water is required. This is effected by having two " return " outlets from the cylinder, the lower being provided with a stop-cock. When this outlet is closed the hot water is stored in the upper part of the cylinder without mingling with the receding cold water, and is therefore available immediately a reserve is accumulated. A few gallons at 150° Fahr. can be had in a very short time in this way; almost as quickly, indeed, as from a geyser, and for a gas consumption of 2 to 3 cubic feet per gallon, according to the time of year and the temperature of the cold supply.

In the second matter of the paper—the comparison between a coal range boiler and a gas boiler—the hot water apparatus consisted of a 25 gallon cylinder with 26ft. run of 1¼ in. primary flow and return, and 157ft. run of 1 inch secondary circulation. The coal range boiler raised the primary flow to 142° Fahr. in two hours, during which time 28 lbs. of best kitchen coal was burnt. The gas boiler, working into and out of the same cylinder, achieved the same temperature in the flow in 30 minutes; and the total gas consumption for 1½ hours, when the thermostat shut down to 8 cubic feet per hour, was 125 cubic feet. Assuming this to signify equality of performance, the cost of the coal would be at London prices, about 4½d.; and the gas would have to be priced at 3s. per 1,000 cubic feet to equal it.

If first cost is an object, perfectly good results can be attained by water heaters with burners controlled by hand. The type of apparatus classed as " circulators," commonly embodies this principle.

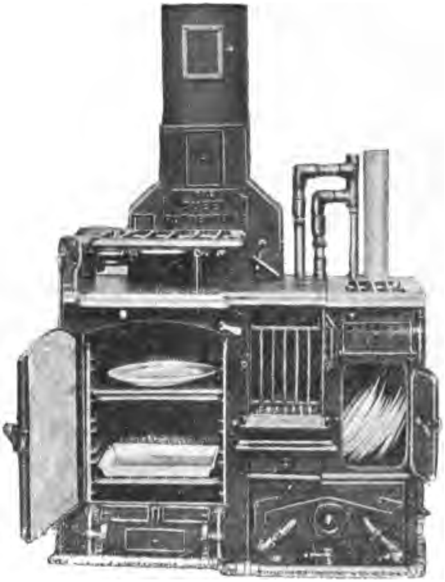


Fig. 53. A Combination Coal and Gas Cooking Range, with Coal or Gas Water Heating.

Where the gas "boiler" is more of a fixture, whether in series with the range boiler or independent, it is expedient to operate it by the aid of a thermostatic gas valve, which automatically reduces the flow of gas to the burner when the return water attains the temperature, say, of 105° Fahr. This means that the whole of the contents of the hot cistern are at bath temperature; so that the consumption of gas need only be as much as will keep the water warm, say, about 8 to 10 cubic feet per hour, according to the length and state of the piping.

Various kinds of thermostats for this purpose are in use. They all depend upon the expansion of a metal or fluid with heat; and should be prompt, sure, and constant in action. There should also be a means of adjustment to permit of varying the minimum flow of gas to particular requirements.

The capacity of a hot-water reservoir should correspond with the customary number of hot baths wanted; the smallest, single-bath domestic set comprising a 20 gallon cylinder with sink-supply cut-off, as illustrated. The idea is that the available storage should be emptied once, at every time of using.

Any amount of heating power can be obtained by massing the boilers in a battery.

Hot cisterns and warm water pipes should always be lagged and cased in to keep in the heat, if possible. Steam quality piping of ample bore, with no elbows, should be used. Where pipes pass through ceilings, partitions, or floors they should have iron sleeves of slightly larger diameter.

The Risk of Gas Explosions and of Asphyxiation.

A FEW words on the aspect of gas in regard to public security will not be out of place. As already remarked (p. 76) gas affords the Safety Light of Civilization. Flat-flame burners should be fixed wherever danger from fire or burglars is recognized as possible. In the case of occupied premises in which an alarm of fire is raised after nightfall, the standing order should be "Turn up all lights!" So that people may find their way to the exits. All "emergency exits" so called should be used often enought to preserve the remembrance of their existence.

It is a popular error that the ordinary service of gas into a building can ever contribute seriously to the conflagration, even should it be impracticable to get at the main cock. The quantity of gas that could escape from a broken service pipe, or a demolished meter, would not amount to anything worth consideration in the mass of burning material.

Actual danger from gas is of two kinds—danger of explosion, and danger of gas poisoning or asphyxiation, commonly termed "gassing." The risk of explosion is much diminished where water-slide pendants have been abolished; and is practically limited to cases where the inevitable fool who is always with us seeks for an escape of gas with a naked light—and finds it.

"Gassing" may be intentional or accidental. Occasionally cases of deliberate suicide by inhalation of gas are reported to the gas offices, and they are usually past help when discovered. It is very desirable, however, for all important gas undertakings to be provided with full life-saving equipment for dealing with serious cases of gassing in the district as well as in the works; and failure to do so, or in the knowledge of how to render "first aid" in this regard always creates a bad impression.

Besides the "smoke helmet" type of equipment (Fig. 54) which is employed for enabling rescue work to be attempted without waiting for an enclosed space to be cleared of gas or fumes, apparatus for and practice in treatment of victims of gassing should be familiar to all gas fitters.

The procedure is, generally speaking, the same as that for the treatment of persons apparently drowned; with the difference that the body must be turned face upward to facilitate the expulsion of gas from the lungs and stomach.

Severe "gassing," with unconsciousness and collapse of the sufferer, must be treated as promptly as possible on the following lines:—

Send for a doctor.

Procure a bottle of oxygen, with a yard of india-rubber tubing, and the key.

Remove the person into the open air. Loosen all clothing about the chest, belly, and neck. Do not allow people to collect round him. Place a rolled-up coat under the shoulder-blades, and practice artificial

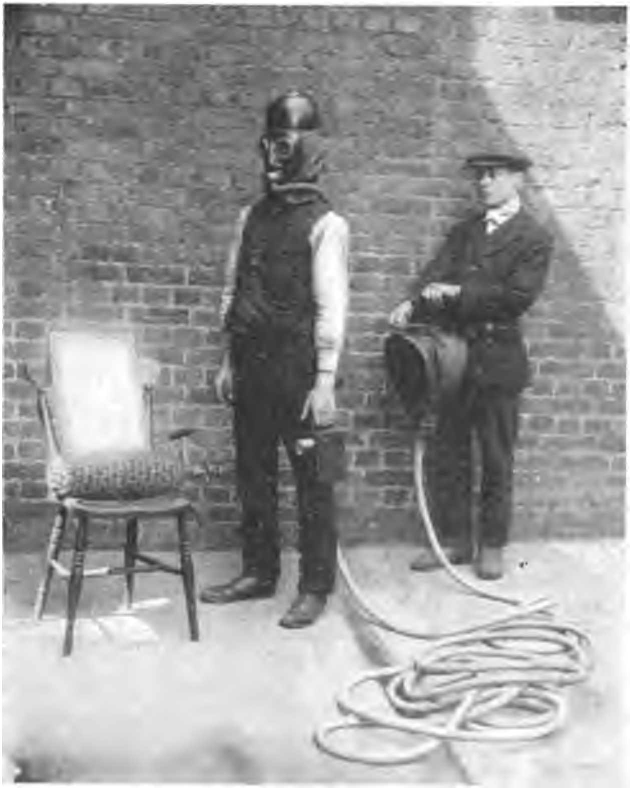


Fig. 54.
"SMOKE HELMET" EQUIPMENT FOR RESCUE WORK.

respiration. Oxygen will be necessary for recovery in bad cases, because the attack is a combination of asphyxiation and blood-poisoning. The use of the "Pulmotor" (particulars of R. Jacobson, 70 Shoe Lane, London, E.C.) is the best known method of treating the worst cases.

After consciousness has been restored care is necessary to avoid a chill. The patient should therefore be warmly wrapped up and sent home to a warmed bed.

Slight gassing, attended with vomiting, can be treated by walking the subject about in the open.

The question may be raised, in regard to cases of gassing of persons indoors, not being gas workmen actually engaged in operations with live supplies, of the period of time necessary for the accumulation of a poisonous or an explosive mixture of gas and air, and of the proportions of such mixtures.

It must be understood that the chief danger of blood-poisoning from unburnt gas proceeds from the presence of carbon monoxide, CO, which forms a stable compound with animal blood that eventually deprives it of the power of sustaining life. This gas is present in town gas in the proportion of from 7 to 9 per cent. if the gas is made from coal alone; or up to 14 or 15 per cent. if a large proportion of carburetted water gas is added to the gas in the process of manufacture.

A test for the presence of CO in a gaseous mixture is to shake it up with a solution of two drops of human blood in 100 cubic centimetres of water. The colour changes to rose-pink.

Breathing an atmosphere containing 20 per cent. of a gas which itself contains 15 per cent. of CO, would in four minutes reduce a man to helplessness.

This would also be a very powerful explosive mixture of town gas and air; being indeed about the composition of the perfect burning mixture. Town gas becomes explosive when mixed with air in the proportion of 1 of gas to 10 of air; and ceases to be explosive when the mixture is 1 of gas to 4 of air. It follows from this that a highly poisonous mixture of town gas and air is also explosive. "Gassing," with more or less acute symptoms, requiring aid, may arise after half-an-hour's exposure to an atmosphere containing from 1 to 5 per cent. of town's gas.

Ordinary persons whose sense of smell is normal can detect when awake the presence of gas in the air, when it is only present in the minute proportion of 1 part in 10,000. Hence, with ordinary care, there is little risk of either poisoning or explosion from gas in ordinary circumstances, unless this warning is neglected.

Escapes of gas in sleeping chambers are more dangerous, inasmuch as there is no certainty that even a strong smell of gas will arouse a sleeping person. Where bedroom chimneys are not stopped up, and especially if the window is left open a few inches at the top, the risk of asphyxiation from an ordinary escape of gas, as, say, from an unlighted burner, of a person lying on a bed, is insignificant.

The Fixing and Care of Gas Engines.

In connecting up a gas engine, the size of the service pipe must be calculated according to the maximum consumption, taken at 20 cubic feet per horse-power of the engine per hour with a reasonable margin, and assuming the pressure at the inlet to be never less than 20-tenths.

If the service is a long one and the street main small it is well to insert a length or two of cast-iron main, say, 9in. diameter, near the engine; so as to provide a store of gas ready to be drawn upon for the first stroke or two, by which time the gas will have begun to flow in the service. This will also act as an extra "anti-fluctuator."

The supply should be controlled by special pressure governors, because the losses due to irregular charges are very great, and if the gas pressure varies the best mixture is not regularly maintained.

Too much gas gives a slow-burning charge, with deposit of soot in the cylinder; which interferes with the lubrication and chokes the valves. Too little gas causes weak explosions, miss-fires and back-firing, with loss of compression. The usual mixture, with gas of about the ordinary 14 candle quality and 500 B.Th.U. calorific power, is about 10 of air to 1 of gas. The lowest working mixture for any quality of gas with tube ignition can be found by making the calorific power of the mixture about 40 B.Th.U. per cubic foot—that is, divide the figure representing the calorific power of the gas by 40 and the quotient will represent the sum of 1 volume of gas and the number of volumes of air required to compose the mixture, thus

$$\frac{\text{600 B.Th.U. Gas}}{\text{40 strength of mixture}} = 15$$

a working mixture with such gas will be 14 of air to 1 of gas. It will be quite possible to work up to strengths of mixture of 50 or even 55 B.Th.U. with suitable control of ignition (magneto) and timing of the combustion. *(Tookey.)*

In testing gas engines actually at work, Mr. Tookey advises that attention should be given to what he calls the "factor value," which is obtained from the indicator card and measured gas consumption by the following formula :—

(1) $H \times F \div I \times V = S.$
(2) $P \div S = \text{Factor};$

in which—

H = Average calorific value of fuel per lb. or cubic foot.
F = Lbs. or cubic feet of fuel consumed per minute.
I = Impulses per minute.
V = Effective volume of cylinder in cubic feet.
P = Mean pressure lb. per square inch (by indication).
S = Mixture strength in B.Th.U. per cubic foot.

This means that if the mean indicated pressure on the piston, per square inch, is in the neighbourhood of 80 lbs., which is a fair working figure, and the calorific strength of the mixture supplied to the cylinder is 40 B.Th.U. per cubic foot, then the "factor value" will be $\frac{80}{40} = 2$; which will be satisfactory under ordinary working conditions, with a reasonable margin.

For various small power purposes, including the raising of gas pressures to a moderate degree for isolated lighting plants, driving small ventilating fans, etc., gas hot-air motors are available.

[Note.—The lectures and publications of Mr. Tookey may be referred to for further details concerning gas engine management.]

ILLUSTRATIONS

OF

BEST EXAMPLES

OF

PUBLIC STREET LIGHTING

BY

THE GAS-LIGHT AND COKE COMPANY,
LONDON.

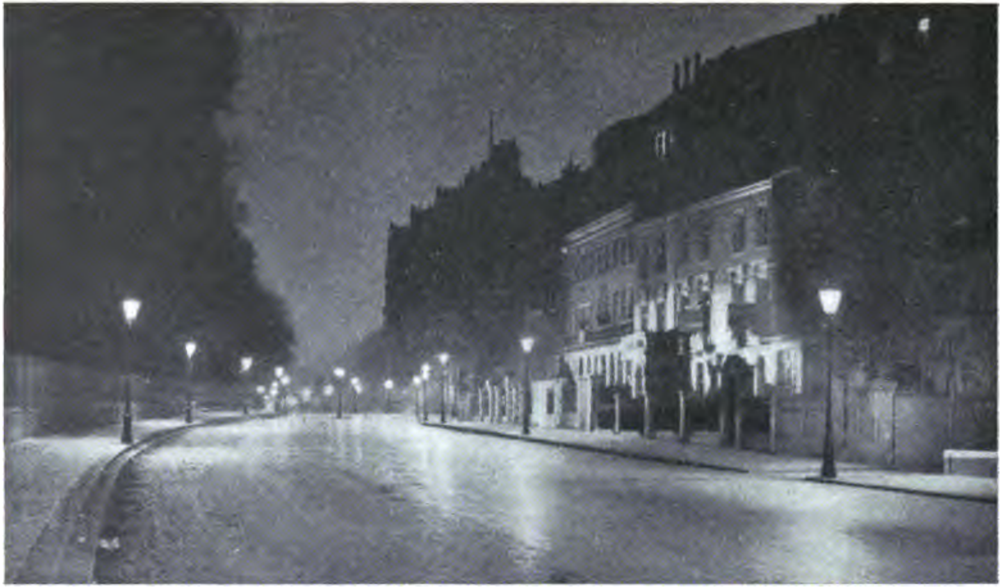


Plate (A). KENSINGTON ROAD, LONDON.

First-class Residential Thoroughfare, sidewalk lamps at ordinary height, low-pressure inverted burners. Good effect, quiet tone.

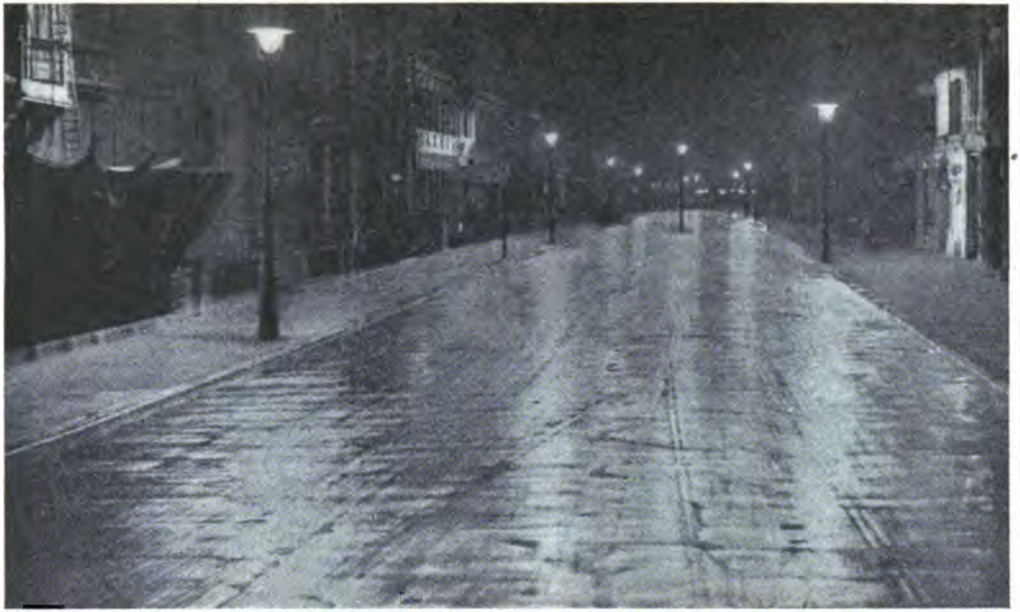


Plate (B). VICTORIA STREET, LONDON.

Heavy, fast traffic, wide roadway and sidewalks; side lighting, 21ft. posts, 1,500 candle-power lamps, 2,500 c.p. at Refuges. Adequate and unobtrusive effect. Posts staggered, 250ft. spacing (average).

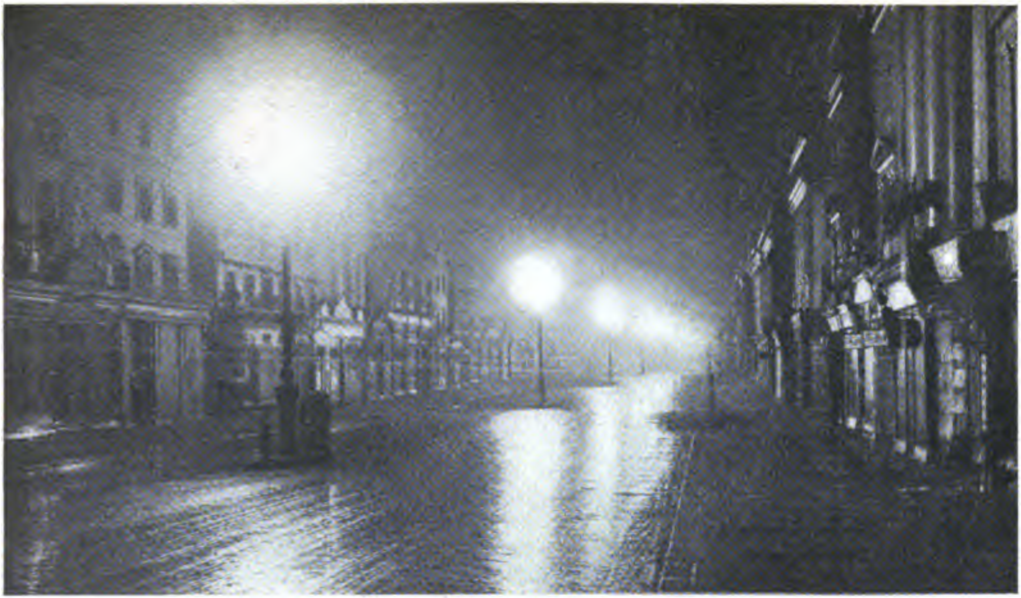


Plate (C). REGENT STREET, LONDON.

Axial Lighting on Posts, forming Refuges. Leaves sidewalk clear; but obstructs road traffic. **3,000** c.p. lamps, about **180**ft. average spacing.

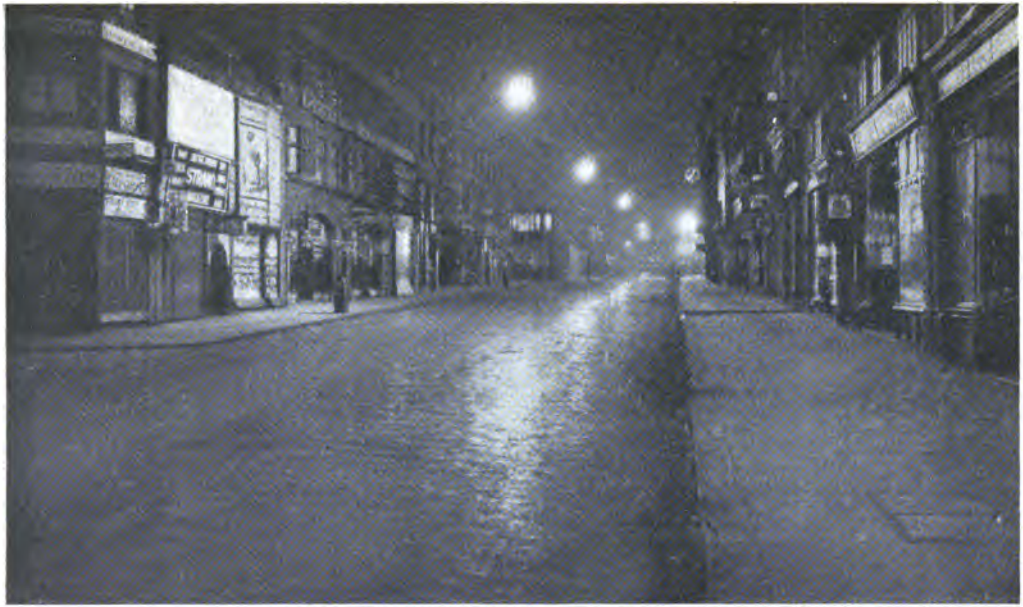


Plate (D). FLEET STREET, LONDON.

A Narrow, much-congested City Thoroughfare. Lights suspended axially, leaving both road and sidewalk clear. 2,000 c.p. double-mantle lamps, 26ft. 6in. above surface; 104ft. spacing.

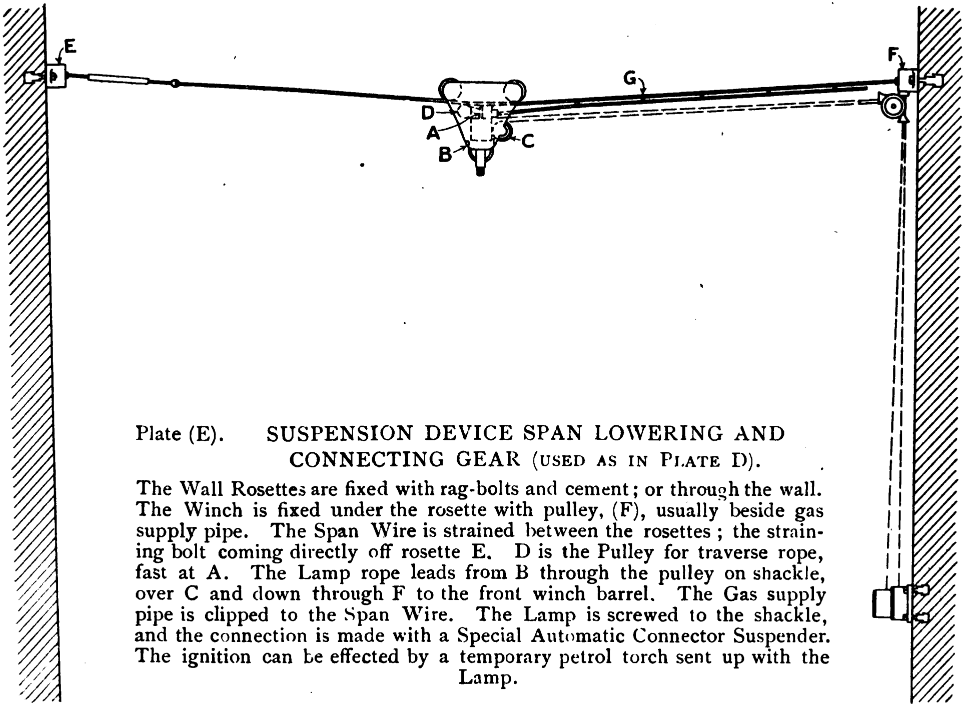


Plate (E). SUSPENSION DEVICE SPAN LOWERING AND CONNECTING GEAR (USED AS IN PLATE D).

The Wall Rosettes are fixed with rag-bolts and cement; or through the wall. The Winch is fixed under the rosette with pulley, (F), usually beside gas supply pipe. The Span Wire is strained between the rosettes; the straining bolt coming directly off rosette E. D is the Pulley for traverse rope, fast at A. The Lamp rope leads from B through the pulley on shackle, over C and down through F to the front winch barrel. The Gas supply pipe is clipped to the Span Wire. The Lamp is screwed to the shackle, and the connection is made with a Special Automatic Connector Suspender. The ignition can be effected by a temporary petrol torch sent up with the Lamp.

APPENDIX.

GLOSSARY OF TECHNICAL TERMS; DEFINITIONS, AND MEMORANDA.

The Board of Trade Unit of Electricity.—This is defined as a quantity of 1,000 watts of electric energy flowing for one hour. It is equal to the supply of electric light by 16—16 candle-power carbon incandescent lamps for one hour; and is also equal to 3,411 British Thermal Units calorific power.

British Thermal Unit.—The quantity of heat represented by warming or cooling one pound weight of water by 1° F.

Calorie (large).—The metric unit of heat, being the quantity of heat required to raise 1 kilogramme of water 1° C. in temperature. It is equal to 3·97 B.Th.U.

Calorific Power.—The apparent heating effect of a fuel exerted upon water, expressed in British Thermal Units (written B.Th.U.). In the case of town's gas, the measurement is made by means of an apparatus of the "geyser" type, in which the heat of the gas is abstracted from the products of its combustion, by running water. The total observed effect is called the "gross" calorific power, and if the amount of heat represented by the liberation of latent heat from the condensed water of combustion is deducted the figure is called the "net" calorific power.

Carbon dioxide gas (CO_2).—The natural product of the complete burning of carbon in air; also of animal respiration. An inert gas, non-poisonous; but incapable of supporting combustion or animal life. Heavier than air—specific gravity, 1·53. Approximately, one cubic foot of town's gas produces in burning one-half its bulk of CO_2. Tests of the ventilation of factories and workshops are made by measuring the proportion of CO_2 in the atmosphere; which is not considered satisfactory if more than 12 parts of 10,000 is detected. This figure refers to the total CO_2 content, most of which would proceed from the respiration of the occupants. Pure CO_2, resulting from the combustion of gas, is harmless up to one vol. per cent.

Carbon monoxide gas (CO).—Forms about 5 to 7 per cent. of straight coal gas, about one-third of carburetted water gas, and rarely more than 10 to 12 per cent. of a " mixed " town's gas. Its calorific measure is nearly the same as Hydrogen, being per cubic foot 342 B.Th.U. It requires for combustion the same proportion of air as Hydrogen, 2·38 vols. per vol. of the gas. It has no " gross " or "net " difference, as it burns to CO_2 only. Its specific gravity is 0·96. It is the product of imperfect combustion of carbon, and does not occur in Nature. It is very poisonous.

Carburetted Water Gas.—This is the so-called " water gas," a mixture of Hydrogen and Carbon monoxide, resulting from passing steam through a bed of incandescent coke, afterwards carburetted with petroleum. Originally introduced into England from the United States as an " enricher " of common coal gas, it is now retained for bulk production when the oil market is favourable. It has a slightly lower calorific power but higher flame temperature than common coal gas of similar illuminating power. When sent ont with this in irregular proportions may cause "popping " and lighting-back of bunsen burners, by reason of its lower air requirement. It has a specific gravity of about 0·60; so that the average specific gravity of mixed town's gas is usually about 0·50.

Conversion of Thermometer Scales.—Fahrenheit to Centigrade, subtract 32, multiply by 5 and divide by 9. Cent. to Fahr., multiply by 9, divide by 5, add 32.

Hydrogen (H_2).—The lightest of the components of town's gas, of which it ordinarily makes about one-half the bulk. Its calorific measure per cubic foot is 344 gross, and 294 B.Th.U. net. It burns to water only, of which it forms with the oxygen of 2·38 cubic ft. of air 329 grains per cubic foot. It is an odourless, invisible gas, never occurring free in Nature. Specific gravity, 0·069, air = 1·0.

Illuminating Power.—The sole standard of quality for town's gas was formerly the power of the light yielded by burning it at the rate of 5 cubic feet per hour, in the most suitable burner for the purpose. The number of spermaceti candles, six to the pound, giving an equal light was taken as the measure of the illuminating power of the gas.

Light-giving Hydrocarbon Gases and Vapours.—It is the presence of certain compounds of hydrogen and carbon, of various composition, from Ethane (C_2H_4) and Ethylene (C_2H_4) up to Benzene and Acetylene which, combining in combustion with the non-luminous components, H_2, CH_4, and CO, produces the luminous effect of town's gas. These components amount, in modern 14 candle gas, to between 2·5 and 4 per cent. of the whole bulk. For calorific calculations they are usually lumped together as (C_n H_m) and their calorific value is taken at about 2,680 B.Th.U. gross, 2,400 net. Air required, 14·25 vols.

Marsh Gas (CH_4).—Forms about one-third of the bulk of town's gas. Its calorific measure per cubic foot is 1,070 gross and 964 net B.Th.U., requiring 9·52 cubic feet of air for its combustion. Its specific gravity is 0·55. It occurs naturally, as "fire-damp," in coal mines; and also in cess-pits, etc., as a product of decaying humus matter.

Nitrogen is the largest gaseous component of air, of which it constitutes four-fifths by volume; oxygen constituting the other fifth. It is inert, non-poisonous, incapable of supporting combustion. It may be found in town's gas in amounts varying from 5 to 10 per cent; but should not exceed the latter figure. Its specific gravity is 0·97.

Oxygen.—The combustion and life-sustaining gas in the atmosphere, of which it constitutes one-fifth of the bulk. It combines with Hydrogen to form water (H_2O). It is also the acid-former. Its specific gravity is 1·105. Air is a mixture of oxygen and nitrogen, not a chemical compound. Hence by increasing the pressure of air upon a burning combustible the action can be intensified up to a point, beyond which the preponderating bulk of nitrogen will extinguish the flame.

Petrol Air Gas.—The name given to air carburetted with the vapour of the light petroleum spirit. If the proportion of vapour used is 5 per cent. and upwards, this mixture will burn quietly. Below 1·5 per cent. the mixture will not ignite or explode at ordinary pressures. At about 1·8 per cent. of the vapour the mixture will not light back in the pipes if expelled under about 5 inches water pressure. It then mingles immediately with sufficient air to burn safely; for which reason it is commonly described as a "non-explosive gas." The truth is that it is not a gas, and that this mixture in the mains is highly explosive. The calorific power of this mixture is from 90 to 100 B.Th.U. per cubic foot, and it will yield a light equal to 9 candles per cubic foot in an incandescent burner.

Specific Heat.—The term applied to express the capacity of substances for absorbing heat, in comparison with water, which is taken as 1 for solids and fluids, by weight. *Air* at about 39° to 40° F. temperature runs about 12·5 cubic feet to the pound. Weight for weight with water at equal temperatures, the specific heat of air is 0·27 nearly. Therefore, the specific heat of air per cubic foot at this temperature in question is

$$\frac{0{\cdot}27}{12{\cdot}5} = {\cdot}02$$

Sulphur in town's gas when properly made is never in the form of sulphuretted hydrogen, but as other comparatively inoffensive compounds, chiefly with carbon. It is liberated, when gas is burnt, in company with the aqueous vapour formed at the same time by the union of the hydrogen with the oxygen of the air, with which it combines to form sulphur acids. These acids mostly condense upon and are absorbed by the lime of ordinary ceilings and walls. They act upon the zinc of brass fittings exposed to them, especially while hot, exhibiting the white sulphate of the metal. This construction, therefore, should be avoided. Sulphur acids, including the obnoxious sulphuretted hydrogen, which tarnishes bright metals, are always present in the air of towns in which coal is burnt; and in foggy weather may exceed many times the quantity of sulphur in gas-lit rooms.

Town's Gas, popularly known as "Gas," is the uncondensible gaseous product of the distillation, or "carbonization" of bituminous Coal in retorts heated externally to a temperature of about 2000° Fahr. This Coal gas, which has a specific gravity of about 0·42, is often mixed with about 25 per cent. of its bulk of Carburetted Water Gas (which see).

Town's Gas, composition of.—Purified coal gas contains in various proportions according to the nature of the coal from which it is made, the combustible components hydrogen, methane, light-giving hydro-carbons, and carbon monoxide; also the incombustible gases carbon dioxide and nitrogen, and it is usually saturated with aqueous vapour, and contains a little sulphur (not as sulphuretted hydrogen). The components of carburetted water gas do not differ in kind, but only in proportion, from those of Coal Gas.

Town's Gas, Combustion Products of.—The products of burning town's gas freely in air are carbon monoxide, water, and a small quantity of sulphurous acid gas.

Town's Gas, Explosive Mixtures of, with Air.—Average town's gas when mixed with air before ignition, in the bunsen burner, becomes non-luminous when the air amounts to about one-third of the bulk of the gas. The mixture will continue to burn at the end of an open bunsen tube, at ordinary main pressures, until the proportion of air reaches upwards of 3 volumes to 1 volume of gas. Such a mixture is said to be

" explosive," and its combustion an " explosion." If the admixture of air is carried to upwards of 9 volumes to 1 volume of gas, the mixture will neither burn nor explode, at ordinary atmospheric pressures, although a pale " cap " might form over a safety-lamp flame in such an atmosphere. The theoretical quantity of air required to combine with the whole of the combustible components of ordinary town's gas, with no excess, is from 5 to 6 vols. to 1 vol. of gas. The most violent explosion would be produced with a small fraction less than the theoretic quantum.

Town's Gas, ignition temperature of.—Town gas in the presence of air, at ordinary temperatures and pressures, will not ignite at any temperature below a red heat, or about 1000° Fahr. (600° Cent.).

Town's Gas, working temperature of combustion.—Anything up to 1200—1300° Cent. with air blast.

Town's Gas, calorific measure of.—When tested with a " total effect " calorimeter, in which the air and gas are burnt in the saturated state (carrying as much aqueous vapour as possible at their temperature), common town's gas, of what is recognized as about the best quality for general purposes, of 13 or 14 candle-power by the now obsolete illuminating power standard, should show a calorific power of 540 B.Th.U. per cubic foot, at normal temperature and pressure.

Town's Gas, odour of.—The distinctive odour of town's gas, which is a valuable property of it in regard to public safety, is noticeable by persons awake and in ordinary possession of their faculties, when the proportion of the unburnt gas in the atmosphere is as little as one part in 10,000.

Volume of any Gas.—For calculations relating to the specific gravity of gases, the standard temperature is taken at 62° Fahr.; because then water, which is the datum substance, weighs 10lbs. to the gallon. In the case of constant pressure at a certain (absolute) temperature, the volume of gas for any other temperature is

$$V^1 = V \frac{t^1 + 461}{t + 461}$$

When the temperature is constant, the absolute volume varies as the absolute pressure, or

$$V^1 = \frac{Vp}{p^1}$$

The formula for ascertaining the volume when both temperature and pressure change is

$$V^1 = V \frac{p\,(t^1 + 461)}{p^1\,(t + 461)}$$

And the volume of one pound weight of air at any temperature and any pressure (absolute) is

$$V = \frac{(t + 461)}{2{\cdot}7074\,p}$$

The expansion of gases under constant pressure is uniform, and is at the rate of $\frac{1}{493{\cdot}2}$ part of the volume at 32° F. for every degree of rise of temperature. Ordinarily, it is taken at 1 per cent. for every 4° F. over or under 60° F.

Water Vapour in Air, or Gas.—Air and all gases that have been in contact with water absorb a certain quantity of its vapour, which varies according to the temperature; and also with the degree of saturation. Thus, at 42° F. the proportion of vapour at the point of saturation will be roughly 1 per cent. At 52° F. it will amount to 1.5 per cent.; at 62° F. it will be 2 per cent.; at 75° F. it will be 3 per cent; and at 80° F. 3·5 per cent. by volume. Air is never perfectly dry, and rarely completely saturated with moisture. Its condition can be ascertained by means of the dry and wet bulb thermometer, which shows the effect of evaporation. The average percentage of saturation in England is about 75. When air is suddenly cooled by a certain amount, it begins to deposit, as condensed moisture, the surplus vapour which it can no longer carry at the lower temperature. This temperature is called the Dew Point. It explains the phenomenon of "steamy windows."

TABLE

Showing the number of cubic feet of Gas for a Penny and a Shilling at ordinary Prices per 1,000 cubic feet.

Number of Cubic Feet for a Penny.	Number of Cubic Feet for a Shilling.	Price per 1000 Cubic Feet.	
		s.	d.
20	240	4	2
21	252	4	0
22	264	3	9
23	276	3	7
24	288	3	6
25	300	3	4
26	312	3	2
27	324	3	1
28	336	3	0
29	348	2	10
30	360	2	9
31	372	2	8
32	384	2	7
33	396	2	6
34	408	2	5
35	420	2	5
36	432	2	4
37	444	2	3
38	456	2	2
39	468	2	2
40	480	2	1

(The "slot" price is usually a few pence per 1000 cubic feet higher than the regular price, to recoup the cost of the fittings supplied without charge, etc)

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